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The American journal of science

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W. G. FARLOW

THE

AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES

VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

WITH FIVE PLATES.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY,
NEW HAVEN.

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'rof. W. G. Farlow.

VOL. XXIX. JANUARY, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

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FOURTH SERIES

VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

No. 169—JANUARY, 1910.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union; $6.25 to Canada. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

Announcement of New Arrivals.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*Dinosaurian Distribution*; by RICHARD S. LULL.

[Contribution from the Paleontological Laboratory, Peabody Museum, Yale University.]

I. Introductory.
II. Classification.
III. Habitats and adaptations.
IV. Geological distribution.
V. Geographical distribution.
VI. Summary of migrations and palæogeography.
VII. Bibliography.

Dinosaurian Distribution.

I. INTRODUCTORY.

THE significance of terrestrial vertebrates of bygone days as aids to geological interpretation, and especially in throwing light upon the isolation and connection of continents, is becoming more and more appreciated.

The dinosaurs, with their known geological range throughout nearly the entire Mesozoic period, and of almost world-wide distribution, are the most significant vertebrates of Secondary times. Add to this their great numbers both of individuals and kinds and the amazing range in their adaptations and one can appreciate the importance of the line of research of which this paper is the first fruit. It constitutes the further elaboration of a presidential address delivered before the American Society of Vertebrate Paleontologists at Baltimore, December, 1908.

As such a work is of necessity to a certain extent a compilation, I can but express my indebtedness to the various authors listed in the Bibliography, of whom my confrère, Professor v. Huene, is the one to whom I owe the most. I am also grateful to my colleagues Professors Schuchert and Barrell for helpful criticisms and suggestions.

II. CLASSIFICATION.

The dinosaurs, because of their great adaptive radiation throughout their long career, seem to be a very heterogeneous group, so much so that Baur (1891) emphatically denied any relationship on the part of the several orders which are included within the group.

They exhibit two distinct lines of cleavage, dividing the super-order into three orders, of which two, the carnivorous, bipedal Theropoda and the herbivorous, quadrupedal Sauropoda, may be grouped together, in spite of great adaptive differences; while the herbivorous, bipedal or quadrupedal Orthopoda stand more aloof and show a vastly greater range of intra-ordinal variation. To the first two orders collectively the name Saurischia has been given by Seeley (1888), while the Orthopoda have been designated by the corresponding title of Ornithischia.

A further differentiation of the Theropoda points to two distinct races. The heavier megalosaurs, typified by *Megalosaurus* of Europe, *Allosaurus* of the American Morrison, and culminating in the huge *Tyrannosaurus* of the Laramie, were the more conservative group, the evolution of which consists mainly in an increase in size, accompanying a relative diminution of the fore limbs, which were never used for locomotion, and an assumption of the prehensile function by hind feet and mouth armament as in birds of prey.

The other carnivores, the compsognathoid forms, were of an aberrant nature, not increasing so markedly in size; but of a more agile character, better fitted to prey upon feebler reptiles, birds and mammals than upon other dinosaurs. Typical members of this sub-order are *Compsognathus* from the lithographic stone of Bavaria and *Ornitholestes* of the American Morrison beds.

The Sauropoda appear and disappear with startling suddenness in the northern hemisphere, though lingering in the southern until the close of the Mesozoic. During this time they undergo but little evolution, and that mainly in the line of a marvelous adaptation for lightness coupled with great strength, especially in the elongated vertebral column. Perhaps the best-known representatives of this group are *Apatosaurus* (*Brontosaurus*), a huge, unwieldly beast, and *Diplodocus*, a lighter, more slender form; both from the Morrison of Wyoming and Colorado. It is a significant fact that the most generalized (*Haplocanthosaurus*) and the most specialized

(*Diplodocus*) among sauropods occur in the same quarry and were therefore contemporaneous. (Hatcher 1903, p. 57).

Of the plant-feeding Orthopoda there are three main types, which have differentiated from the original stock; one, the unarmored Ornithopoda, paralleling the carnivores in general bodily contour and bipedal gait, though bringing the fore feet to the ground when occasion demanded. Like the carnivores they too included a greater and a lesser race. The former, like *Iguanodon* of the Wealden of Europe and *Camptosaurus* of the American Morrison, culminated in *Trachodon* of the late Cretaceous; while the latter are represented by the fleet *Laosaurus* of North America and *Hypsilophodon* of Europe.

On the other hand, two groups of armored, secondarily quadrupedal dinosaurs arose, possibly derived from the same branch of the Orthopoda, possibly of independent origin. These were the Stegosauria, the defensive sort with small head and heavy body armor sometimes forming, over part of the body at least, a veritable cuirass or carapace; and the more aggressive Ceratopsia with huge armored skull, but, so far as our knowledge goes, bereft of any special body mail. The first are represented by the British *Polacanthus* and the American *Stegosaurus*, while the last have a splendid representation in that most grotesque of dinosaurs, *Triceratops* from the American Laramie.

V. Huene (1907–1908, p. 351) derives the Sauropoda from the early Theropod dinosaurs of the Trias, seeing in the genus *Plateosaurus* the annectant type. In his scheme of relationships (v. Huene 1909, p. 22), however, he seems to defer the divergence of the Sauropoda from the Plateosauridæ until the Lias, which would hardly give time for the profound change shown by either *Cetiosaurus* or *Dystrophæus* of the Dogger. It is my impression that the divergence occurred earlier in Triassic time.

Of annectant forms, linking the Theropoda and Orthopoda, none is suggested by v. Huene among known types, as our known record of the latter does not go back far enough in time. Of the Stegosauria, *Scelidosaurus* of the English Lias seems to be the most primitive as it surely is the oldest; it is, however, still removed from the Ornithopoda and a common ancestor must again be sought in more remote strata.

The Ceratopsia may have their earliest representative in *Stenopelix* of the Wealden of Brückeburg. V. Huene (1907–1908, p. 374) has shown strong points of resemblance between the pelvis of *Stenopelix* and that of *Triceratops*. Whether, as he suggests, one can derive the phylum from the Scelidosauridan stem, or whether the group represents an independent offshoot from the Orthopod stock, is not quite clear.

These relationships are expressed in the table (figure 1), which is largely compiled from lesser ones by v. Huene (1907–1908, pp. 340, 375, 377; 1909, p. 22).

III. HABITATS AND ADAPTATIONS.

In order to comprehend the remarkable geographical distribution of the dinosaurs, it is necessary to investigate the character of their various habitats, the conditions they were forced to meet and the marvelous degree of adaptation to the environment which they underwent.

I imagine the conditions which gave to the dinosaurs their initial evolutionary trend were such as are thought to have prevailed, beginning in the Permian, throughout Triassic time. This is well shown in the region now known as the Connecticut valley. The older notion of the estuarine origin of these deposits has been abandoned in favor of the idea that they were of terrestrial origin, the climatic conditions being those of semi-aridity with areas here and there which were subject to inundations occurring in times of torrential rains such as are observed to-day under similar climatic conditions in different portions of our globe. This lends color to the view that the early dinosaurs were truly terrestrial types, with marked cursorial adaptation, indicated in the free, bipedal stride and compact, bird-like foot which is shown by the fossil footprints.

V. Huene (1907–1909, pp. 396–401) derives the Theropoda and Parasuchia from one stem, the supposition being that the distinguishing characteristics were developed during the oldest Trias through adaptation. Increasing aridity of climate would render it necessary for an animal to go farther afield for water and possibly for food and thereby place a premium on good powers of locomotion, so that selection would be very active in weeding out the unfit or inadaptable lines. This locomotor adaptation in the quadrupedal stage is beautifully shown in the Parasuchian genus *Stegomus* (Lull 1904 B, pp. 147–148) from the Connecticut valley Trias (Rhætic), evidently a persistent type which, possibly because of the retention of armor, remained a quadruped though long of limb and with the greater portion of the weight borne on the hinder extremities. *Stegomus*, I imagine, though belonging, morphologically, to a very different race, represents a stage in the adaptation of the dinosaurs which was reached early in the Trias.

Many modern lizards are amazingly swift of movement, but their journeys are brief and the rapidly moving types are small. It is a well known fact that a number of lizards, notably *Chlamydosaurus*, when startled, rise on the hinder limbs and run with a truly bipedal gait (Sayville-Kent 1898, p. 341). It is significant that the bipedal lizards, so far as my knowledge goes, are all found in semi-arid climates—Australia, Southwestern United States. This tendency toward bipedalism, with a consequent profound alteration of the hind limbs and pelvis, both in bone and musculature, seems therefore to have developed to meet the need of greater range of movement necessitated by increasing aridity, and was the prime factor in the early evolution of the dinosaurian race.

So strongly was this feature impressed, that the main lines of dinosaurian evolution, whether plant or animal feeders, were cursorial, terrestrial types, though, as new conditions arose, or were met with during their forced migrations, aberrant types of marvelous complexity and range of specialization developed. These aberrant forms, from the fact that their remains were more readily preserved, are the ones best known to us and have colored our whole conception of the dinosaurian race.

When the plant-feeding Orthopoda arose we do not know. *Nanosaurus* (v. Huene and Lull 1908) is known from the upper Trias (or lower Jurassic) of Colorado, while in the possibly contemporaneous beds of the Connecticut valley there have been found many footprints which Lull (1904 A, pp. 499–509) has shown to belong to plant-feeding types of general proportions not unlike those of their theropod allies, but differing mainly in the feebly prehensile character of the little, blunt-toed manus, the imprint of which is sometimes seen. The Theropoda, on the other hand, had a strong, grasping hallux, as a rule rotated to the rear of the foot so as to be in opposition to the other toes, and a manus with powerful claws, which had already sacrificed fully the function of locomotion to that of prehension. The Orthopoda could give rise to secondarily quadrupedal (Dollo 1905) forms, the Stegosauria, the Ceratopsia; the Theropoda, on the other hand, had cast the die in favor of absolute bipedalism and stalked on upon the hind limbs to the end of their career.

While both small and large forms prevailed at the close of the Trias, the differentiation, if we except the character of the pubis, is largely owing to opposite habits, acquired apparently in the remote Trias, very early in the dinosaurian evolution.

The carnivores, as has been said, are relatively conservative in their evolution, except for the differentiation into the greater megalosauroid forms and the lesser compsognathoid types. The Theropoda were evidently the most mobile of all dinosaurs, free to migrate wherever other creatures lived which could possibly be utilized for prey, for not only do we find them the world over, with the exception of Asia (vide infra p. 31) north of India, but practically wherever dinosaurs of whatever sort are found.

The Sauropoda.

During the Triassic, the carnivores had spread to other conditions and had given rise to a new order, the Sauropoda, no longer truly terrestrial, but inhabiting the bayous and swamps of the numerous deltas which fringed the continental shores. This change of habitat was far-reaching in its effects, for rapid locomotion was no longer necessary and a certain degeneracy resulted—whether the carnivorous ancestors had attained bipedalism or whether the Sauropoda were primitively quadrupedal I cannot say. Increase in size was accompanied by an elongation of the neck to get a greater range of feeding with as little bodily movement as possible and it necessitated as well a diametric change in diet, for with increasing bulk, no longer finding the animal food of their forbears adequate or readily obtainable, they took to an herbivorous feeding habit which required but little change in the mouth armament.

The modern Iguanidæ show a certain parallelism with the Sauropoda, for while the primitive diet is carnivorous (insectivorous) "some of the most striking forms are herbivorous, e. g. *Iguana*, *Amblyrhynchus*, and *Basiliscus*." (Gadow 1908, pp. 528, 533.) Moreover, one finds within the family not only semi-aquatic adaptation, but even semi-marine. The last is shown by *Amblyrhynchus cristatus*, which "inhabits the rocky and sandy strips of coast of most of the Galapagos Islands, feeding on certain kinds of algae, which it has to dive for, since these plants grow below tide-marks."

The precise food of the Sauropoda is a matter of doubt. Dr. Hay (1908, p. 674), in discussing that of *Diplodocus*, the most highly specialized member of the order, sums up the expressions of opinion as follows: "Hatcher suggested that the teeth might have been useful in detaching from the bottoms and shores the succulent aquatic and semi-aquatic plants that must have grown there in abundance. Osborn [1889, p. 214] says that the 'food probably consisted of some very large and nutritious species of water plant. The anterior claws may have been used in uprooting such plants * * * The plants may have been drawn down the throat in large quantities without mastication.' * * * Holland [1906, p. 240] thinks that the teeth were better adapted for raking and tearing off from the rocks soft masses of clinging algæ than for securing any other forms of vegetable food now represented in the waters of the world.

"To the present writer [Hay] the suggestion of Dr. Holland has in it more of probability than any of the others presented. If the food-plants sought by *Diplodocus* had been large and such as required uprooting by the great claws of the reptile, the prehension and manipulation of the masses would have been liable to break the slender teeth and would certainly have produced on them perceptible wear. * * *

"It is more probable that the food consisted of floating algae than of plants that were loosely attached to the bottoms of stagnant bayous and ponds. . . . In addition to various algae were probably other floating plants."

The teeth of the Sauropoda, notably *Morosaurus* and *Aptosaurus* (*Brontosaurus*), are much more robust and frequently show decided wear. This wear, however, is along the edges on either side of and sometimes including the apex; which could readily be accounted for by abrasion of the alternating teeth of the opposing jaw and which could not be due to scraping of vegetation from the rocks. The food of these animals may have been more in keeping with the character of that mentioned by Osborn.

It is interesting to note in this connection, à propos of the question of the digestibility of huge masses of unmasticated vegetation, the occurrence of "stomach stones" or "gastroliths" (Wieland 1906) which seem to have had an important function in aiding in the trituration of the food. Wieland records the occurrence of such polished flint pebbles in immediate association with the remains of a large sauropod observed at the northern end of the Big Horn Mountains. Pebbles, presumably gastroliths, were also found by Wieland with the type of the Sauropod genus *Barosaurus* from near Piedmont, South Dakota.

Dr. Hay (loc. cit., p. 673–674) further says: "Hatcher has discussed at length the nature of the region in which the species of *Diplodocus* and their allies lived, as well as the habits of the Sauropoda in general; and the present writer [Hay] agrees with him on most points. Hatcher believed that the Atlantosaurus [Morrison] beds were deposited, not in an immense freshwater lake, as held by some geologists, but over a comparatively low and level plain which was occupied by perhaps small lakes connected by an interlacing system of river channels. The climate was warm and the region was overspread by luxuriant forests and broad savannas. The area thus occupied included large parts of the present states of Colorado, New Mexico, Utah, Montana and the Dakotas. In his memoir on *Diplodocus* Hatcher compares the conditions prevailing in that region during the Upper Jurassic [Lower Cretaceous] to those now found about the mouth of the Amazon and over some of the more elevated plains of Western Brazil.

"In such regions the rivers, fed from distant elevated lands, must have been subject to frequent inundations. The beds of the streams were continually shifting, and there existed numerous abandoned channels that were filled with stagnant water. An animal that lived in such a region would be compelled to adapt itself to a more or less aquatic life, and this adaptation would be reflected to a greater or less extent in the structure of the animal."

Through the courtesy of Dr. Holland, I have been able to study somewhat critically an undoubted sauropod footprint from the Morrison dinosaur quarry at Cañon City, Colorado. Hatcher figures a cast of this track in his memoir on the osteology of *Haplocanthosaurus* (1903, fig. 23, p. 161). The figure is somewhat deceptive, however, in that it was taken from a plaster cast of the specimen which in turn is a natural cast of the original impression made by the living animal and which is therefore in relief. The surface of the specimen itself is covered with deep pits caused by a solution of the calcareous cement which bound the grains of sand together, thus allowing the latter to be washed out. In the photograph the casts of these pits, being in relief, give the impression of pebbles, whereas the rock in the quarry is a fine-grained, cross-bedded sandstone of uniform texture, without appreciable clay, and not gravelly at all. A microscopic study of the sand-grains themselves show them to be angular with slightly abraded corners, sand of aqueous deposit; but apparently laid down in a lake or bayou, rather than in a normal river as indicated by the absence of clay and the presence of a lime cement. The cross-bedding which the rock exhibits could readily have been made by wave action along the shores of a comparatively shallow delta-lake or bay, and the track, which is that of a very young animal, was evidently made under water. The character of the sediment does not give evidence of much vegetable matter at the particular point where the track was made. The footprint is that which one would expect from the known character of the sauropod foot, and is evenly impressed throughout as though the animal's weight were borne equally over the entire sole, evidence in favor of a true walk rather than a sprawling crawl, at any rate when the body was partly water-borne.

I believe these animals to have been truly aquatic though capable of coming ashore where the substratum was sufficiently firm to support the immense weight, and, while they show no trace of swimming appendages, they doubtless could swim as a hippopotamus does or, as Hay (1908, p. 667) has implied, like a colubrid snake "which makes fair progress in the water, notwithstanding the absence both of a compressed tail and of a vertical fin."

The Wealden formation of England is thus described by Geikie (1903, pp. 1180–1181). "The Purbeck beds bring before us evidence of a great change in the geography of England towards the close of the Jurassic period. They show how the floor of the sea, in which the thick and varied formations of that period were deposited, came to be gradually elevated, and how into pools of fresh and brackish water the land leaves, insects, and small marsupials of the adjacent land were washed down. These evidences of terrestrial conditions are followed in the same region by a vast delta formation, that of the Weald, which accumulated over the south of England, while the marine strata were being deposited in the north. Hence two types of Lower Cretaceous sedimentation occur, one where the strata are fluviatile (Wealden), and the other where they are marine (Neocomian)."

In Wyoming the Morrison beds lie directly upon the marine Baptanodon beds of Marsh in which Belemnites abound. Lying between this and the main dinosaur-bearing layer are about 156 feet (Loomis 1901, pp. 192–193) of variegated sandstones and clays, of which bed No. 13, 82½ feet above that which contains *Baptanodon* itself, seems to represent the first of the freshwater (or brackish) series, as it contains an abandoned dinosaur quarry in Como Bluff. This would seem to indicate that in the Morrison, conditions very similar to that of the Wealden prevailed and that in each instance access to the sea on the part of the sauropod inhabitants was not only possible but actually probable, as the littoral realm seems to have been the highway of immigration of this order of dinosaurs.

The Morrison beds, lying as they do in a great synclinal trough, and at the time of their deposition but little above sea level, probably were drained, in the southern portion at least, into the sea, which lay some two hundred and fifty miles (Schuchert 1909, Late Upper Jurassic Chart) to the southward. This drainage outlet because of its very low gradient may again have given conditions similar to those of the Amazon (vide supra p. 8), so that the passage of the Sauropoda across the area included in the present state of New Mexico would appear to have been perfectly feasible. Evidence which may be corroborative is found in Madagascar, in a locality east of the bay of Narinda, wherein were discovered the remains of *Titanosaurus* in a matrix containing the marine *Mytilus madagascarensis* and foraminifera (Boule 1896, p. 348).

Orthopoda.

The Orthopod dinosaurs were adapted to a very different kind of food from that of the Sauropoda, developing in the course of their evolution a more and more perfect dental mechanism for chopping into short lengths the relatively firm terrestrial vegetation. The toothless anterior part of the mouth was sheathed in a leathery or horny beak which reached its highest perfection in the Ceratopsia and which constituted the prehensile, while the teeth, borne in the posterior portion of the jaws, formed the masticatory part of the mouth; best developed in the Ceratopsia (Hatcher 1907, pp. 43–46) on the one hand and the Trachodontidæ (Brown 1908, pp. 52–53) on the other.

The Sauropoda and Theropoda had only prehensile teeth and did not masticate their food at all. This shows quite clearly that, so far as feeding habits go, none of the three great groups of dinosaurs came into competition with each other, except that the carnivores did occasionally devour the others, and that, in so far as the Sauropoda and Orthopoda were concerned, the habitat was necessarily different; the latter being in the main terrestrial, the former amphibious. In no other way can we account for the marked differences in distribution of the two orders which, reduced to its final analysis, has gone so far that the two groups are rarely found in the same quarry even within the same region and geological formation. For example, "Quarry 13" (Gilmore, 1909, p. 299) in Como Bluff, Wyoming, from which several of Professor Marsh's more important type specimens came, contains almost entirely the remains of Orthopoda, *Camptosaurus*, *Dryosaurus*, *Stegosaurus*; of Carnivores, *Allosaurus* and *Cœlurus*, while but a single Sauropod, the type of *Morosaurus lentus*, an extremely young individual, was found in association. On the other hand, the famous Bone Cabin Quarry, situated but a few miles distant, had yielded up to 1904 (Osborn, 1904, p. 694) sauropods, 44; stegosaurs, 3; smaller herbivorous dinosaurs, 4; large carnivorous dinosaurs, 6; small carnivorous dinosaurs, 3; showing the Sauropoda to be vastly more numerous than the other plant-feeding varieties, and evidently implying a distinct habitat from that represented by "Quarry 13."

Within the Orthopoda the marked differentiation into Ornithopoda, or unarmored types, and the Stegosauria and Ceratopsia, or armored forms, seems to have been due to their different modes of defence, presumably against the omnipresent carnivores, though the existence of enemies other than dinosaurs, such as the crocodile *Goniopholis*, is not unlikely. The Ornithopoda, which were the most conservative in their evolution among the Orthopoda, retained the cursorial character of their ancestry, relying evidently upon celerity and speed rather than upon weapons or armor for defence against their sanguinary foes. The ideal of this type of dinosaur was perhaps *Laosaurus* of North American Morrison and its old world representative *Hypsilophodon* of the English Wealden. Later *Trachodon*, and probably its ancestor *Claosaurus*, the remains of which are found repeatedly in marine rocks, became in their turn semi-aquatic, possibly in their search for food because of competition with the great armored forms. They did not, however, rely on increasing bulk for immunity against attack as did the Sauropoda; but, by means of a powerful, laterally compressed swimming tail may have been as active as crocodiles in the water while still retaining a means of comparatively rapid locomotion on land. The defencelessness of these creatures, so far as armor is concerned, has been beautifully shown in the "mummified" specimen of *Trachodon*, discovered in 1908 by C. H. Sternberg, in Converse County, Wyoming, and now preserved in the American Museum of Natural History. Professor Osborn (1909, pp. 793–795) says of it: "The first and most surprising impression is that the epidermis is extremely thin, and that the markings are excessively fine and delicate for an animal of such large dimensions. There is no evidence in any part of the epidermis either of coarse tubercles or of overlapping scales. In all parts of the body observed it is entirely composed of scales of two kinds: (1) larger pavement or non-imbricating scales, (2) smaller tubercular scales." Osborn speaks not only of the "vigorous use of the tail as a balancing, and perhaps partly as a swimming organ," but also tells us that the "manus is completely encased in the integument, and was thus web-footed." Evidence for aquatic or semi-aquatic life.

The armored dinosaurs make their first appearance in *Scelidosaurus* of the English Lias, the possible ancestor of all of the subsequent mailed types. The earliest forms were probably bipedal, but, as time went on, and the armor increased in bulk and weight, we find these dinosaurs becoming secondarily quadrupedal (Dollo 1905), losing all celerity of movement and becoming sluggish, slow moving, living citadels of well-nigh impregnable character. In habitat they were doubtless terrestrial, as in the case of the earlier Ornithopoda with which their remains are found associated. A curious differentiation of armored dinosaurs occurred, correlated with a marked difference in the mode of defence, in that the more aggressive, mentally alert Ceratopsia used the head both for offence and defence, while the stegosaurs seem to have used the tail. *Stegosaurus* proper, which developed to an extreme this method of defence as well as a remarkable body armament of huge probably upstanding plates, became too highly specialized to survive and apparently died out early in the Lower Cretaceous. Its allies, however, still lived on until the close of the Mesozoic, developing over the rear of the body in *Polacanthus* of the English Wealden, and later in *Ankylosaurus* of the Laramie, a veritable cuirass, glyptodon-like in its perfection, covering what seemed to be the most vulnerable portion of the body.

That the Ceratopsia were aggressive fighters among themselves, as the cattle are to-day, is known from the frequent punctures of skull and frill, broken horn-cores, and such sanguinary evidences. That they held their own against the terrible carnivores of their time is shown by their survival until the close of dinosaurian history.

The environment of the Cretaceous Orthopod dinosaurs and of the attendant carnivores is described by Stanton (1909, pp. 280–282) as consisting of great areas but slightly elevated above the level of the sea and occasionally actually beneath it, wherein are found fresh-water, brackish water, or marine deposits. Upon these great marshes vegetation became established, and land animals, and those of the streams and lagoons as well as the bays and estuaries, sought their appropriate habitats.

In speaking of the conditions prevailing toward the close of the Cretaceous, Hatcher (1893, p. 142; Hatcher, Marsh, Lull 1907, p. 194) says: "The Ceratops beds are thought to afford evidence in themselves of having been deposited not in a great open lake, but in a vast swamp with occasional stretches of open waters, the whole presenting an appearance similar to that which now exists in the interior of the Everglades of Florida. This condition would account for the frequent changes from one material to another in the same horizon.* * *

"The conditions that prevailed over this region during the period in which the Ceratops beds were deposited were probably those of a great swamp with numerous small open bodies of water connected by a network of water courses constantly changing their channels. The intervening spaces were but slightly elevated above the water level or at times submerged. The entire region where the waters were not too deep was covered by an abundant vegetation, and inhabited by the huge dinosaurs (*Triceratops*, *Torosaurus*, *Claosaurus*, etc.), as well as by the smaller crocodiles and turtles and the diminutive mammals, all of whose remains are now found embedded in the deposits."

For the terrestrial Orthopoda, such as *Camptosaurus* and *Iguanodon*, the cycads and ferns which grew in such profusion during their time would supply ample nourishment. *Stegosau-*

rus, however, has relatively feeble teeth, and must have fed upon the most succulent of terrestrial plants. The Ceratopsia, living as they did toward the close of the Upper Cretaceous, were surrounded by a virtually modernized flora, and hence may have had feeding habits very similar to those of the subtropical browsing ungulates of to-day.

Trachodon, however, presents more of a problem on account of its undoubted aquatic habits. Here the anterior, toothless part of the mouth in the most highly specialized types became broadened and depressed into a duck-like form, and, while undoubtedly sheathed with a horny or leathery integument, probably did not have the shearing mechanism so perfectly developed as in the true terrestrial plant-feeders. On the other hand, the dental battery reaches its greatest perfection in *Trachodon*, consisting as it does of "from 45 to 60 vertical and from 10 to 14 horizontal rows of teeth, so that there were more than 2,000 teeth altogether in both jaws." (Brown, 1908, p. 53.) The immense number, especially of those in reserve, implies a very rapid wear and consequent replacement of the teeth; which, together with the sharp, serrated, shearing edge which the collective teeth of a jaw present, argues strongly in favor of the idea as expressed by Brown (loc. cit., p. 55) that some species of Equesetæ, the remains of which are the most abundant among the plant relics entombed with these dinosaurs, supplied them with food. The broad duck-like muzzle would be admirable for dislodging the rhizomes from their resting place, while the abundance of silica in the cuticle of the plant would necessitate just such a dental battery as the Trachodonts possessed for its proper mastication.

IV. GEOLOGICAL DISTRIBUTION.

Both geologically and geographically the dinosaurs show a peculiar discontinuous distribution, due in large measure to the imperfection of our records, but also to the fact that they were principally terrestrial types and that the preservation of their remains in water-laid rocks is largely the result of accident.

Theropoda.

Geologically the Theropoda have the greatest range, as they are first found in the Lower Muschelkalk of Europe and continue on until the end of the Mesozoic.

Triassic.

Of the Triassic forms, a very complete series is found in central Europe, of which one of the most primitive genera is *Thecodontosaurus*, which also had the widest distribution both geographically and in time (see fig 2). From the *Thecodonto-*

saurus stem are derived, as side lines, the Newark dinosaurs *Anchisaurus* and *Ammosaurus* of the Connecticut valley; while the first known of these, *Megadactylus polyzelus* from Springfield, Massachusetts, v. Huene (1906, pp. 115–118) refers to the genus *Thecodontosaurus* itself. *Tanystrophæus*, ancestral to the delicate, hollow-boned Cœluridæ, begins also in the Muschelkalk, and while differing widely from *Thecodontosaurus*, its successor *Cœlophysis*, from beds in Colorado equivalent to the Upper Keuper of Europe, converges again toward the Thecodontoid phylum, so that the later representatives, *Cœlurus* on the one hand and the Compsognathoid forms on the other, are closely approximated.

In the Lower Keuper a new genus, *Zanclodon*, appears in Europe, of greater size than its contemporaries, and from which v. Huene (1909, p. 20) would derive *Ceratosaurus* of the Morrison with no annectant forms. There are, however, among the Connecticut valley footprints (Rhætic), besides numerous ones referable to the Thecodontoid types (*Anchisauripus* Lull—1904, p. 468), those of a large carnivore with powerful anterior claws but with a relatively feeble hallux. This track which Hitchcock called *Gigandipus* (Lull, loc. cit., p. 492) because of its great size, may well have been made by a member of the Zanclodon phylum, the bones of which are as yet unknown in these deposits.

The Middle Keuper ushers in another genus in the form of *Teratosaurus;* giving rise, in the Rhætic, according to v. Huene, to two main branches, from one of which arose, through *Gressylosaurus* and *Euskelosaurus*, the great Megalosaurian line, the other giving rise, through *Plateosaurus*, to the Sauropoda. This seems to me, however, to place the divergence of the Sauropoda somewhat too late in time; to the implied phylogeny I take no exception.

The Connecticut valley forms, which had reached great profusion, to judge from the abundance and variety of their footprints, are contemporaneous with the European Rhætic. Footprints apparently of equivalent age and character are found in New Mexico as well.

The lower Keuper beds contain *Thecodontosaurus* and possibly *Massospondylus* in India (Lydekker 1890, p. 22), while the Upper Keuper entombed the former genus in Australia.

The Upper Karoo beds of Africa, referred by v. Huene to the Rhætic and by Broom (1907, p. 161) to the Lower Jura (Stormberg Beds), contain *Thecodontosaurus*, *Euskelosaurus* and *Massospondylus*, all Triassic types.

Jurassic.

During Jurassic time the record is confined practically to England and the adjacent parts of France until the ushering in of the North American Morrison and Potomac toward its close.

While several species of carnivores are found in England and France during this period, they are all referred to the genus *Megalosaurus* with the exception of the Kimmeridgian *Streptospondylus* of England and *Compsognathus* of equivalent age from the lithographic limestone of Solenhofen, Bavaria.

Dr. A. Smith Woodward (1906, pp. 1–3) has recently described a Megalosaurian ungual phalanx from the Lower Jurassic of Victoria, Australia. He does not, however, suggest a more precise correlation of the beds with those of Europe.

Lower Cretaceous.

The American Morrison in the West and the basal Potomac (Patuxent–Arundel) in the East have yielded a number of Theropoda; from the Potomac, *Allosaurus*, the American representative of *Megalosaurus* and *Cœlurus;* while the Morrison has produced, in addition to these forms, *Creosaurus* and *Labrosaurus*, the horned carnivore *Ceratosaurus*, and the agile "bird-catching" dinosaur *Ornitholestes.*

In Europe the Wealden, probable equivalent in part to the American Morrison, has produced numerous remains of *Megalosaurus.* This genus is also reported from the Albian or Gault of France and from the Bellasien of Portugal, considered by Chaffat to be midway between the Aptian and Cenomanian.

Upper Cretaceous.

In the Upper Cretaceous, ushered in by the Cenomanian, the European species of Theropoda are, almost without exception, referred to the genus *Megalosaurus*, a well-nigh incredible range, Lias to Danian, for a single genus, even of a relatively conservative type. Depéret (1899, p. 692) has referred a carnivore from the Danian (Rognac) of Montagne-Noire, France, to the genus *Dryptosaurus*, first made known from the Upper Cretaceous of New Jersey.

The New World carnivores, on the other hand, have been given various names; of these the principal types are *Dryptosaurus* of the New Jersey Greensand and the Judith River (Senonian) of Montana and Alberta and *Tyrannosaurus* of the Laramie (Danian) among the huge Megalosaurs; while the lesser race is represented by *Ornithomimus* of the Judith River beds, a probable derivative from *Ornitholestes* of the

Morrison. From the Guaranitic beds (Danian) of Patagonia two genera of carnivores, *Genyodectes* (Woodward 1901) and *Loncosaurus* (Ameghino 1900, p. 61), both similar to *Megalosaurus*, have been described.

The Sauropoda.

The oldest undoubted Sauropod dinosaur thus far recorded is *Dystrophæus*, described by Cope (1877), from the Red beds of the Painted Canyon in southeast Utah, which he refers to the Trias, but which v. Huene (1904, pp. 320–321), upon the evidence offered by Whitman Cross, believes to be the equivalent to the Dogger. Doubtless owing to the dearth of Jurassic continental deposits, the American record is a blank from this time until the Morrison and its equivalent, the Lower Potomac of Maryland. Sauropoda appear in England with the Bathonian (Great Oölite) in the form of the generalized *Cetiosaurus*.

The Oxfordian has produced *Ornithopsis*, the Kimmeridgian *Ornithopsis*, *Bothriospondylus* and *Pelorosaurus;* the Portlandian, the first of these; while in the Lower Cretaceous Wealden we find *Cetiosaurus*, *Pelorosaurus*, *Morosaurus* and *Titanosaurus* (Lydekker non Marsh). *Cetiosaurus* and *Pelorosaurus*, v. Huene believes, represent parallel phyla giving rise, in the first instance, to the aberrant American *Brachiosaurus* and *Haplocanthosaurus* of the Morrison, while *Pelorosaurus*, through an early *Morosaurus* as a central type, gives rise to *Atlantosaurus* and *Apatosaurus* (*Brontosaurus*) on the one hand, and *Diplodocus* on the other, being succeeded in time by *Titanosaurus* (Lydekker) which ranges as high as the uppermost Cretaceous.

The American basal Potomac beds have produced *Pleurocœlus*, which is also found in the Wealden of England and Purbeckian of France. The Trinity sands of Texas, of probable equivalent age to the upper Aptian, contain the remains of *Morosaurus*, a typical Morrison genus.

In the southern hemisphere, in Africa, Madagascar and India, in beds of an age approximately equivalent to the Cenomanian, there have been found *Titanosaurus* and allied genera, such as *Gigantosaurus*, *Bothriospondylus* and, in Patagonia in the Guaranitic beds, *Titanosaurus*, *Argyrosaurus* and the relatively small aberrant *Microsaurus*.

Depéret (1889, p. 692) has also described *Titanosaurus* from the Rognac, Danian, of Saint Chinian in the south of France, the last record of the Sauropoda in Europe.

Orthopoda—Ornithopoda.

The Ornithopod dinosaurs, which exclude the armored types, make their first appearance in the North American

Upper Triassic, the possible equivalent of the Rhætic, being represented in the bone by *Nanosaurus*, of the Hallopus beds near Cañon City, Colorado, described by Marsh as a carnivore, but which v. Huene and Lull (1908, p. 143) have lately referred to this order. This type comes from the Upper Trias or Lower Jura of Colorado and is absolutely unique.

Williston, in a letter to the author dated Cañon City, Colorado, July 11, 1909, says: "After a careful study of the locality and region the conclusions I reach are: Nothing more definite as to the age of the Hallopus beds can be said than was given by Marsh. In my opinion they are either uppermost Trias or Lower Jurassic, though possibly of Middle Jurassic age. No fossils of any kind have ever been found below them in the Cañon City region. The type [of *Hallopus*] was found between 60 and 70 feet above the Red beds, doubtless of Triassic age. The intervening strata are distinctly conformable with the Red beds. All the known Morrison fossils from Cañon City are from above the Hallopus horizon, from one to three hundred feet, though numerous fragments of sauropods in the hillside suggest the possibility of less interval between them. There is no persistent red sandstone stratum in the Hallopus horizon. * * * my conclusion is that, until other fossils are found to fix more definitely their age, it is unwise to assign definitely either Triassic or Jurassic age to them. Jura-Trias will express this uncertainty."

Impressed upon the rocks of the Newark system, the equivalent of the Old World Rhætic, in the Connecticut valley and New Jersey are numerous footprints which Lull (1904, p. 499) has shown to pertain to ornithopod forms, the genus *Anomœpus* unquestionably. Two other genera may also belong to the Ornithopoda, *Eubrontes* of larger size and the aberrant *Otozoum*, the bipedal tracks of which indicate a foot unlike that of any known dinosaur. The footprints included under the genus *Anomœpus* show a considerable range in size but are all such as could have been made by forms like *Nanosaurus* and *Hypsilophodon*.

England again gives us the only record of Jurassic types, if we eliminate *Nanosaurus* and the Morrison forms, *Camptosaurus prestwichii* described as *Iguanodon* being found in the Kimmeridge clay. The other Jurassic types which have been referred to *Camptosaurus* Gilmore (1909, pp. 289–292) considers as invalid so far as the genus is concerned. The Oxfordian has yielded *Cryptodraco* (*Cryptosaurus*) which v. Huene (1909, p. 21) considers as ancestral to *Camptosaurus*, the central type of this group.

From the American Morrison are *Camptosaurus*, and a lesser form *Laosaurus* and its relative *Dryosaurus*, which, together with the persistently primitive Wealden *Hypsilophodon*, v. Huene derives from the Colorado *Nanosaurus*. Lull (1910) will report *Dryosaurus* also from the basal Potomac beds of Maryland, and Gilmore (1909, pp. 392–395) has described a *Camptosaurus* from the Lakota in South Dakota.

The Wealden of England and especially of Belgium has yielded remarkably preserved specimens of *Iguanodon*, the successor of *Camptosaurus*. *Iguanodon* is in turn succeeded in the Cenomanian of England by a type referred to the American genus *Trachodon*, but somewhat questionably.

In America, the Niobrara, the equivalent of the European Turonian, has yielded the type of *Claosaurus agilis*, which is followed in the New Jersey Greensand and in probably equivalent beds of North Carolina by *Trachodon* (*Hadrosaurus*).

In the West, *Trachodon* is found in the Judith River beds and again in the Laramie, where it lingers on until the final extinction of the dinosaurian race at the close of the Mesozoic.

The European Cenomanian has produced *Craspedodon* in Belgium and *Mochlodon* from the Gosau formations of Austria. *Rhabdodon*, found in Rognac of southern France and in the Mæstricht beds of Belgium and Holland, both of the Danian period, is probably the closing member of the race in Europe.

Armored Orthopoda—Stegosauria.

The Stegosaurs have their first known representative in *Scelidosaurus* of the English Lias, beyond which the record is blank until we come to *Dacentrus* (*Omosaurus*) of the Kimmeridgian, which appears to be the central type in the evolution of this group. The Morrison yields *Stegosaurus*, which some authors have identified with the European *Dacentrus*, but which appears to be an aberrant side branch derived also from the Scelidosaurian stem. In the basal Potomac beds of Maryland several teeth and more questionably a vertebrum (Lull 1910) are described as *Priconodon* and referred to the Stegosauria.

The Purbeckian of England has also yielded *Priconodon*, while from the Wealden come *Polacanthus* and *Hylæosaurus*, the latter being found in Belgium as well as in England. *Acanthopholis*, from the English Cenomanian, v. Huene makes the connecting link with *Ankylosaurus* of the Laramie.

Intervening forms in the series, however, are probably represented by *Nodosaurus* from the Pierre (Turonian) of Colorado, while *Stegopelta*, recently described by Williston (1905, pp. 503–505) from the Lower Benton of Wyoming, and *Palæoscincus* of the Judith River are closely related if not identical with *Ankylosaurus* of the Laramie. All three, according to Williston, were derived from *Polacanthus* of the Wealden of Europe.

The Gosau beds of Wiener Neustedt near Vienna, probably equivalent to our Judith River, contain a number of armored forms such as *Struthiosaurus* (Nopcsa 1902) and *Acanthopholis* (Nopcsa 1902) some of which, at least, probably pertain to the same race.

Ceratopsia.

The Ceratopsia have a relatively brief career,—*Stenopelix*, the pelvis of which resembles that of *Triceratops*, being the earliest possible representative among known forms. It is found in the Neocomian of Germany. The remains described by Seeley (1881, pl. xxviii, fig. 4) from the Gosau formation under the name of *Cratæomus* (=*Struthiosaurus;* Nopcsa 1902) contain what appears to be a ceratopsian left supra-orbital horn-core which would seem to represent a stage of evolution equivalent to *Ceratops* of the American Judith River. Nopcsa (1902, p. 7) is of the opinion, however, that the horn-like bone in question represents a dorsal spine after the manner of those of *Polacanthus*. This, together with the total absence of two-rooted teeth of the ceratopsian sort among the number preserved at Vienna, casts grave doubt upon the existence in Europe of this remarkable group.

The American Judith River (= Belly River of Canada) contains two stages in the evolution of the Ceratopsia, *Monoclonius* and *Ceratops*, as well as the somewhat aberrant *Centrosaurus* described by Lambe (1904). The Laramie deposits which follow later after a hiatus of some 2,000 or more feet of marine strata contain the terminal members of this race, *Triceratops* and *Torosaurus*. The geological distribution and phylogenies are shown in figure 1.

V. GEOGRAPHICAL DISTRIBUTION.

Theropoda.

The geographical distribution of dinosaurs presents some very interesting problems, some of which, at first sight, are difficult to explain.

By far the widest spread forms are the carnivorous Theropoda (fig. 2), evidently the most adaptable and of a nature not so subservient to a peculiar kind of food, which was apt to be local in distribution, as in the case of the plant-feeding forms. These carnivores are reported in practically every locality where herbivorous dinosaurs have been found, as they seem to

FIG. 1.

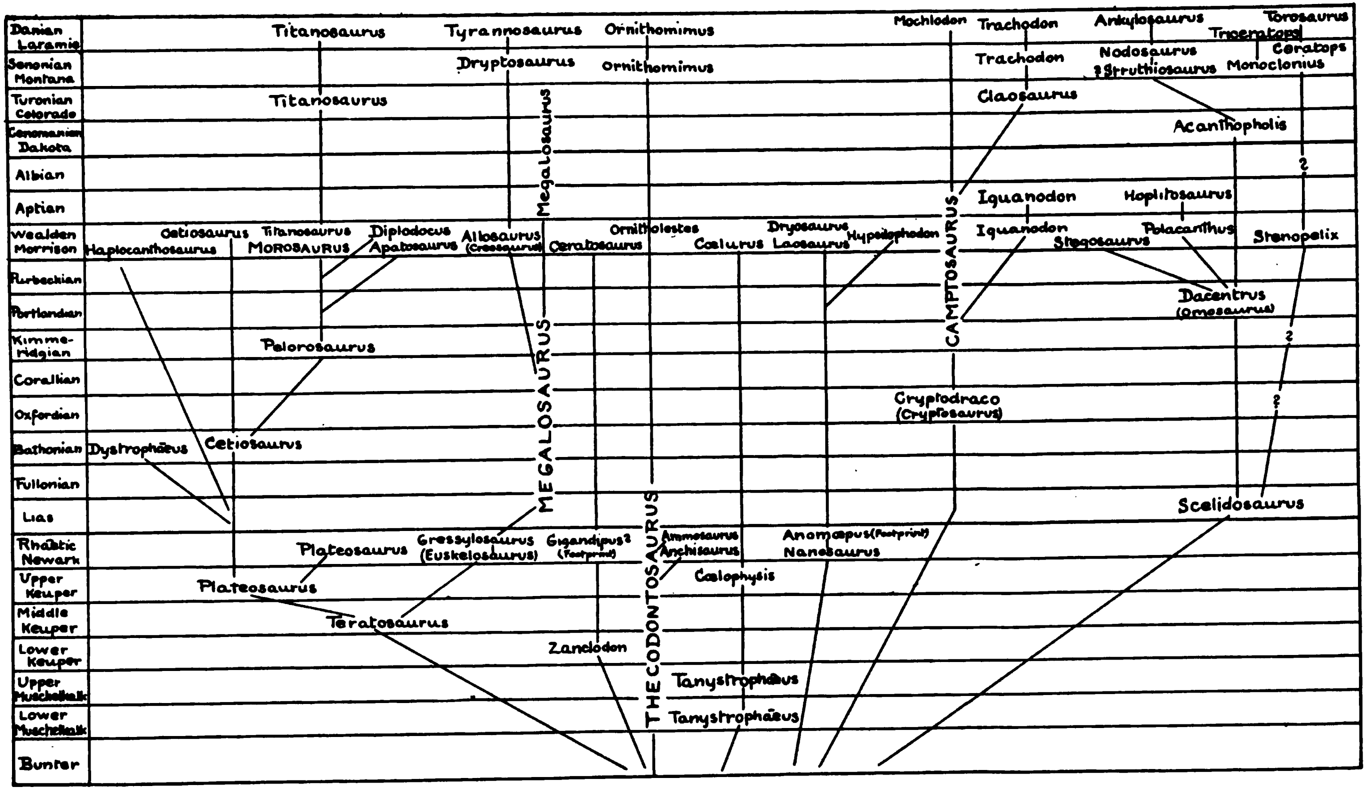


FIGURE 1. Phylogeny and geological distribution of the principal dinosaurian genera.

have accompanied the latter in all of their wanderings. In addition to this they had, during Triassic times, deployed rapidly before our records give us evidence of the existence of the herbivores.

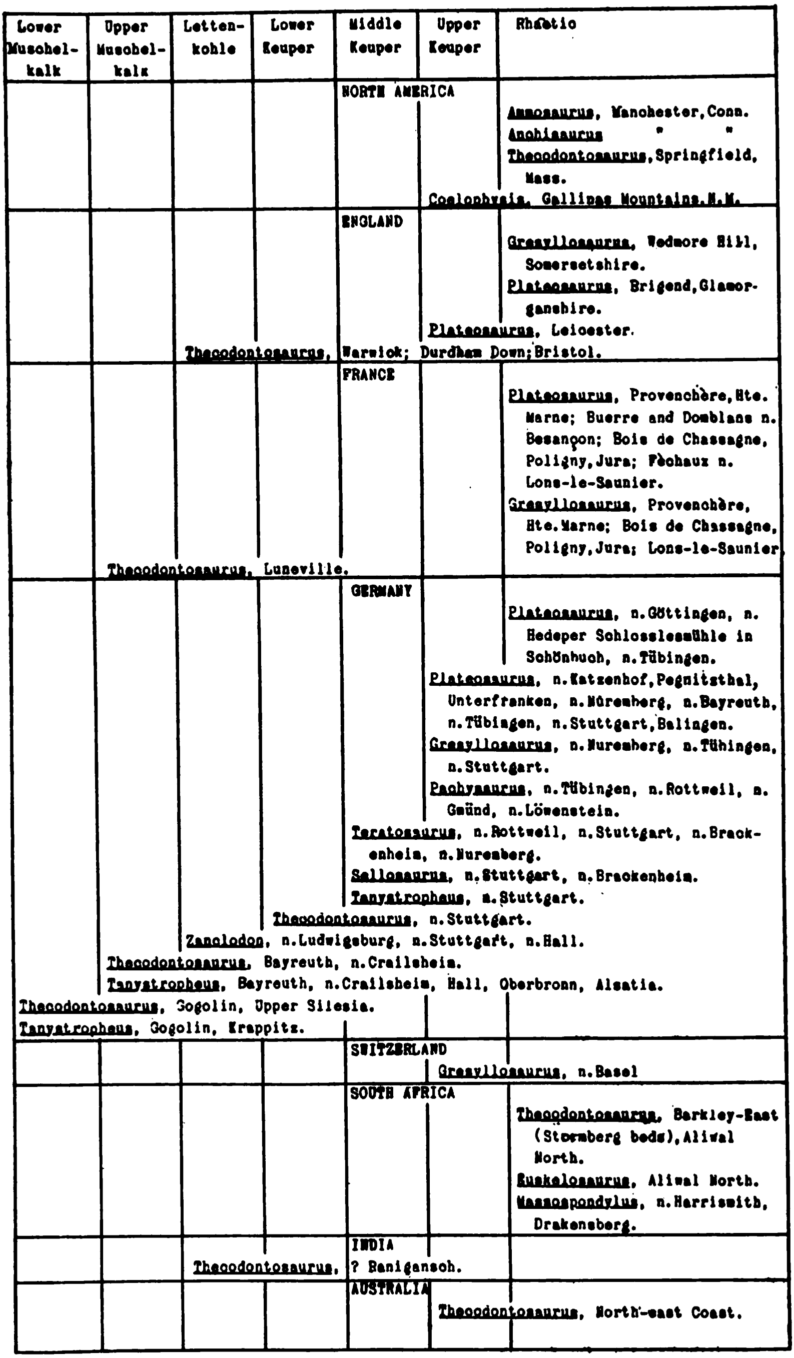
The oldest recorded Theropoda, those of the Lower Muschelkalk, are found in Germany, but we have no proof that this was the center of dispersal. Indeed v. Huene (1908, pp. 100-101) is of the opinion that one must go farther west, where a great continent extended from England to America, to find the conditions which, we have imagined, must have given rise to the dinosaurian race. During the Keuper, particularly, "a brackish sea and swamp extended from England to Eastern Germany as far as the Scandinavian, East Prussian and Bohemian borders, where another great northern continent began and extended eastward."

The semi-arid continent of Triassic time would doubtless be the chosen habitat, the swamp regions the place where the remains of wandering individuals might more readily be preserved.

During the Trias, the Theropoda spread in one direction through Germany, France, England, and in the other to eastern and finally to western North America, which was reached not later than the Upper Keuper. On the other hand, they migrated southward in the Old World to the Gondwana continent, for in the Lettenkohle time we find them in India, in the Upper Keuper in Australia, while South Africa was reached at least by Rhætic time.

What the precise line of march was is somewhat doubtful—I imagine, however, it was southward to what is now northern Africa, thence east to India and Australia, and south to the Cape Colony. We have no recorded evidence of Triassic dinosaurs in South America or in New Zealand. I should hesitate to infer that they had not reached South America during this period, though, as we shall see, the first remains to be found are not older than the Wealden. New Zealand, however, has yielded a rich Triassic flora, together with the remains of labyrinthodonts, implying extensive terrestrial deposits though not the ideal dinosaurian habitat; but as Theropoda are found in all sorts of deposits, even marine, that feature is not especially significant. The total absence of the dinosaurs from New Zealand deposits of any age; the presence in the Permian and Trias of labyrinthodonts; the presence to-day of the absolutely unique *Hatteria*, the sole survivor of its order, dating its ancestry also from the Permian; the presence of no tailed amphibia, of one rare species of frog, of a few lizards, which Heilprin tells us cannot pass the sea as adults, but do in the egg as they are found on remote oceanic islands to which they

Fig. 2.



Lower Muschelkalk | Upper Muschelkalk | Lettenkohle | Lower Keuper | Middle Keuper | Upper Keuper | Rhaetic

NORTH AMERICA

Ammosaurus, Manchester, Conn.
Anchisaurus " "
Thecodontosaurus, Springfield, Mass.
Coelophysis, Gallinas Mountains, N.M.

ENGLAND

Gresslyosaurus, Wedmore Hill, Somersetshire.
Plateosaurus, Brigend, Glamorganshire.
Plateosaurus, Leicester.
Thecodontosaurus, Warwick; Durdham Down; Bristol.

FRANCE

Plateosaurus, Provenchère, Hte. Marne; Buerre and Domblans n. Besançon; Bois de Chassagne, Poligny, Jura; Fèchaux n. Lons-le-Saunier.
Gresslyosaurus, Provenchère, Hte. Marne; Bois de Chassagne, Poligny, Jura; Lons-le-Saunier
Thecodontosaurus, Luneville.

GERMANY

Plateosaurus, n. Göttingen, n. Hedeper Schlosslesmühle in Schönbuch, n. Tübingen.
Plateosaurus, n. Katzenhof, Pegnitzthal, Unterfranken, n. Nüremberg, n. Bayreuth, n. Tübingen, n. Stuttgart, Balingen.
Gresslyosaurus, n. Nuremberg, n. Tübingen, n. Stuttgart.
Pachysaurus, n. Tübingen, n. Rottweil, n. Gmünd, n. Löwenstein.
Teratosaurus, n. Rottweil, n. Stuttgart, n. Brackenheim, n. Nuremberg.
Sellosaurus, n. Stuttgart, n. Brackenheim.
Tanystropheus, n. Stuttgart.
Thecodontosaurus, n. Stuttgart.
Zanclodon, n. Ludwigsburg, n. Stuttgart, n. Hall.
Thecodontosaurus, Bayreuth, n. Crailsheim.
Tanystropheus, Bayreuth, n. Crailsheim, Hall, Oberbronn, Alsatia.
Thecodontosaurus, Gogolin, Upper Silesia.
Tanystropheus, Gogolin, Krappitz.

SWITZERLAND

Gresslyosaurus, n. Basel

SOUTH AFRICA

Thecodontosaurus, Barkley-East (Stormberg beds), Aliwal North.
Euskelosaurus, Aliwal North.
Massospondylus, n. Harrismith, Drakensberg.

INDIA

Thecodontosaurus, ? Banigansch.

AUSTRALIA

Thecodontosaurus, North-east Coast.

Figure 2. Distribution of the Triassic Theropoda (adapted from v. Huene).

FIG. 3.

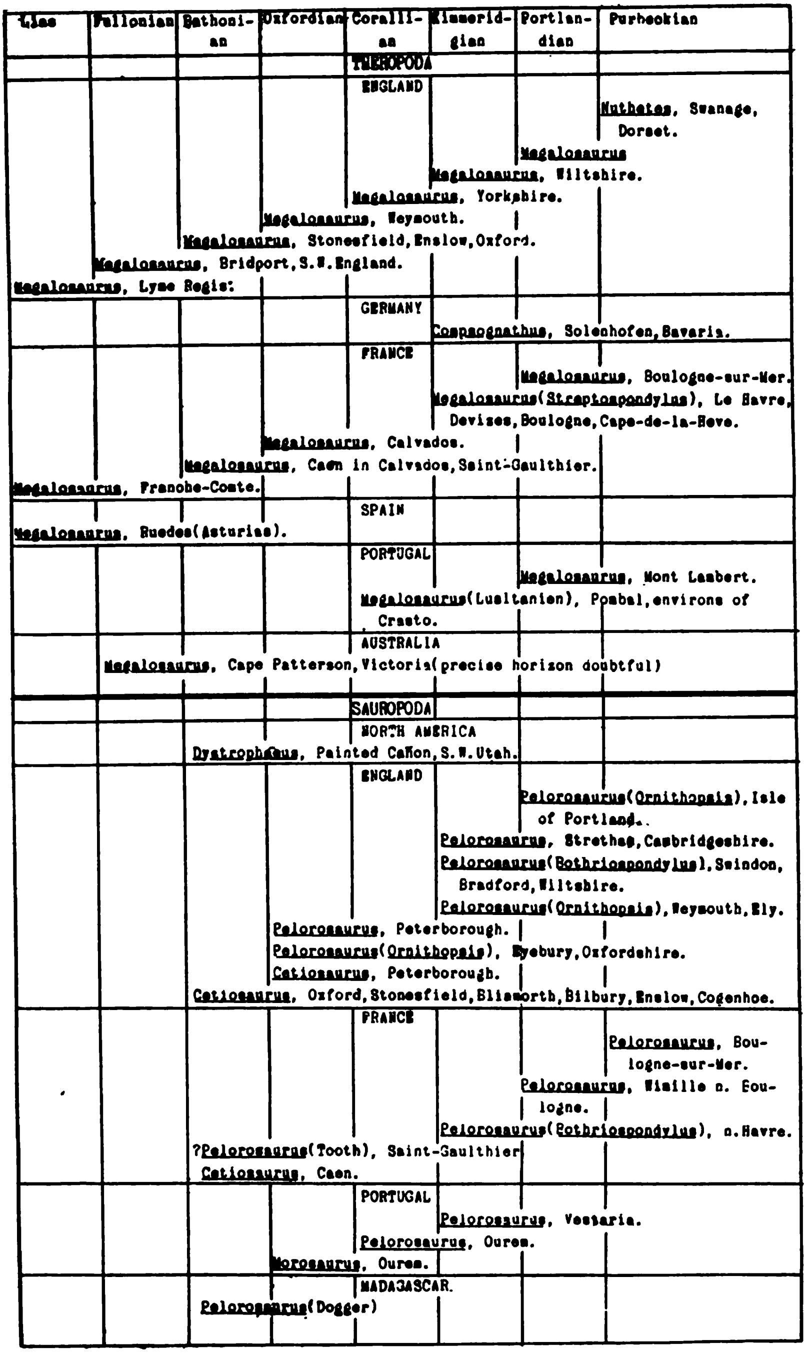


FIG. 3. Distribution of the Jurassic Theropoda and Sauropoda (original).

may have found means of introduction by floating timber; the absence of any indigenous mammals other than bats, a rat, and the Maori dog, the introduction of which may be as readily accounted for;—all of these evidences seem to me to point to an utter isolation geographically on the part of New Zealand since the close of the Permian. De Lapparent's maps (1906) indicate a continuous New Zealand-Australian connection into the basal Eocene—long after the breaking up of the Gondwana continent. The biological evidence which I have given strongly opposes this view.

During Jurassic times the record of Theropoda (fig. 3) is practically continuous in England and Europe, and one Megalosaur has been described by Smith Woodward (1906) from the Lower Jurassic of Cape Patterson, Victoria, Australia, about the nearest point toward the unattainable New Zealand.

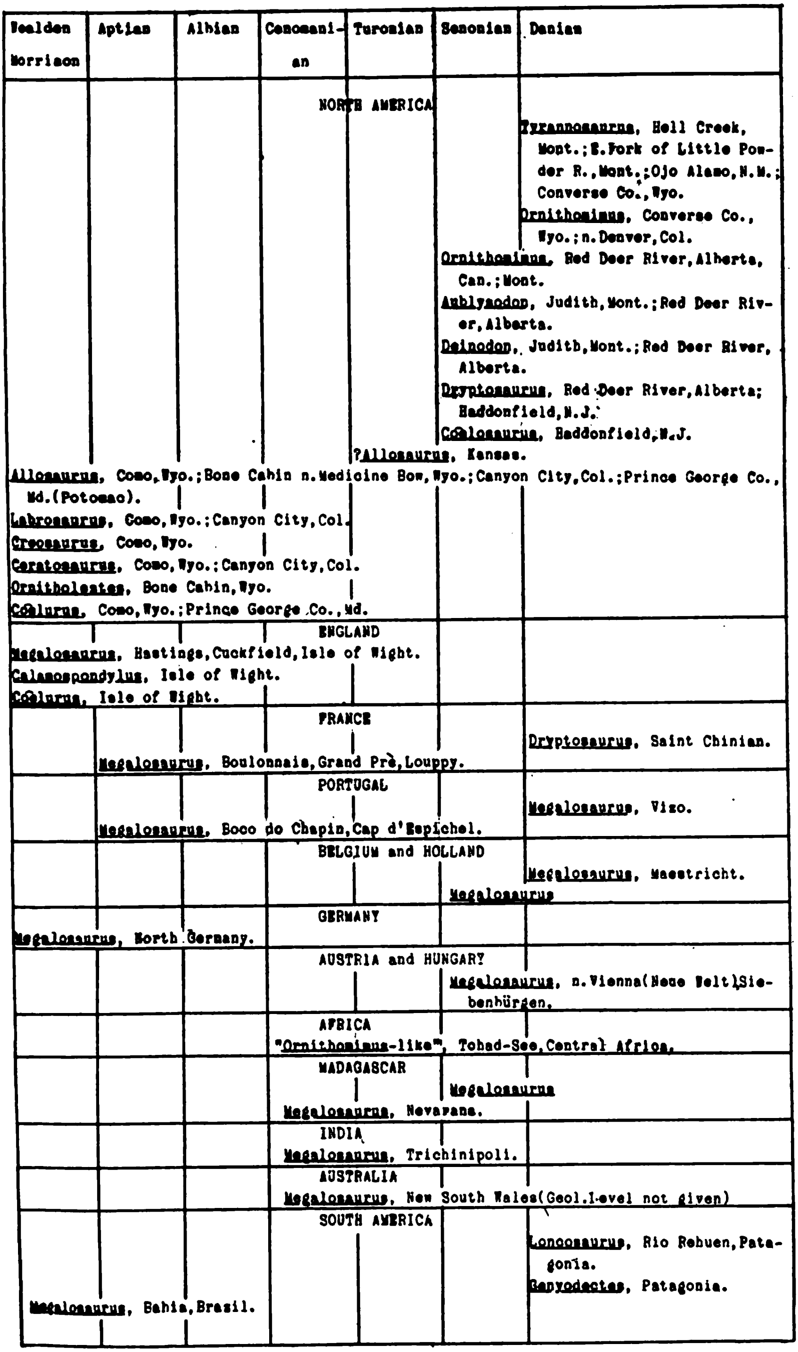
For Africa, South America, and most strikingly for North America, the known Theropod reçord is a perfect blank throughout the Jurassic, though the remains of other dinosaurs are sparingly known. This is unquestionably due to dearth of known terrestrial deposits in Africa and North America, for the few which exist have thus far yielded no dinosaur remains. As for South America, it may be that the migrant dinosaurs did not arrive until the beginning of Lower Cretaceous time.

The Lower Cretaceous (fig. 4) saw the Theropoda at their widest extent, the Wealden of England and the Morrison and basal Potomac of North America having yielded a marvelous assemblage of types. In Europe their record is seen somewhat scatteringly throughout the Lower and Upper Cretaceous, indicating that they inhabited the whole area throughout the period. In North America, while there are extensive breaks in the continuity of the record, the great numbers and wide distribution at the beginning and end imply an equally extensive distribution in time and space. Central Africa, near the Tchad See, yields theropod remains during the Cenomanian; Madagascar, India and Australia as well in beds of approximately equivalent age; while in the neighborhood of Bahia, Brazil, in beds of an age equivalent to the Wealden, is found the first positive indication that these forms had reached South America. Having once found a foothold in South America, the Theropoda lingered on until the close of the Cretaceous, as their remains are reported from several localities in Patagonia in the Guaranitic (Danian) strata.

Sauropoda.

The Sauropoda (fig. 5) are also very widespread though evidently local in distribution owing to necessary peculiarities in habitat and food. Their appearance in time is startling, as

FIG. 4.



Wealden Morrison | Aptian | Albian | Cenomanian | Turonian | Senonian | Danian

NORTH AMERICA

Tyrannosaurus, Hell Creek, Mont.; E. Fork of Little Powder R., Mont.; Ojo Alamo, N. M.; Converse Co., Wyo.

Ornithomimus, Converse Co., Wyo.; n. Denver, Col.

Ornithomimus, Red Deer River, Alberta, Can.; Mont.

Amblyaodon, Judith, Mont.; Red Deer River, Alberta.

Deinodon, Judith, Mont.; Red Deer River, Alberta.

Dryptosaurus, Red Deer River, Alberta; Haddonfield, N.J.

Cœlosaurus, Haddonfield, N.J.

?Allosaurus, Kansas.

Allosaurus, Como, Wyo.; Bone Cabin n. Medicine Bow, Wyo.; Canyon City, Col.; Prince George Co., Md. (Potomac).

Labrosaurus, Como, Wyo.; Canyon City, Col.

Creosaurus, Como, Wyo.

Ceratosaurus, Como, Wyo.; Canyon City, Col.

Ornitholestes, Bone Cabin, Wyo.

Cœlurus, Como, Wyo.; Prince George Co., Md.

ENGLAND

Megalosaurus, Hastings, Cuckfield, Isle of Wight.

Calamospondylus, Isle of Wight.

Cœlurus, Isle of Wight.

FRANCE

Dryptosaurus, Saint Chinian.

Megalosaurus, Boulonnais, Grand Prè, Louppy.

PORTUGAL

Megalosaurus, Vizo.

Megalosaurus, Boco do Chapin, Cap d'Espichel.

BELGIUM and HOLLAND

Megalosaurus, Maestricht.

Megalosaurus

GERMANY

Megalosaurus, North Germany.

AUSTRIA and HUNGARY

Megalosaurus, n. Vienna (Neue Welt), Siebenbürgen.

AFRICA

"Ornithomimus-like", Tchad-See, Central Africa.

MADAGASCAR

Megalosaurus

Megalosaurus, Nevarana.

INDIA

Megalosaurus, Trichinipoli.

AUSTRALIA

Megalosaurus, New South Wales (Geol. level not given)

SOUTH AMERICA

Loncosaurus, Rio Rebuen, Patagonia.

Genyodectes, Patagonia.

Megalosaurus, Bahia, Brasil.

FIG. 4. Distribution of the Cretaceous Theropoda (original).

they are found in strata which v. Huene refers in each case to the Dogger but at points far removed geographically, in England, in Utah, and in Madagascar (v. Huene, 1909, p. 14). If v. Huene is correct in his derivation of the group from the Theropod genus *Plateosaurus*, I should look to this swampland extending during the late Trias from England to Eastern Germany, before alluded to (vide supra p. 21) as the place of origin of the race. That they reached such remote places before their very existence is indicated in our records points to the incompleteness of the latter and good powers of migration along the swamp and delta formations which fringed the continental shores.

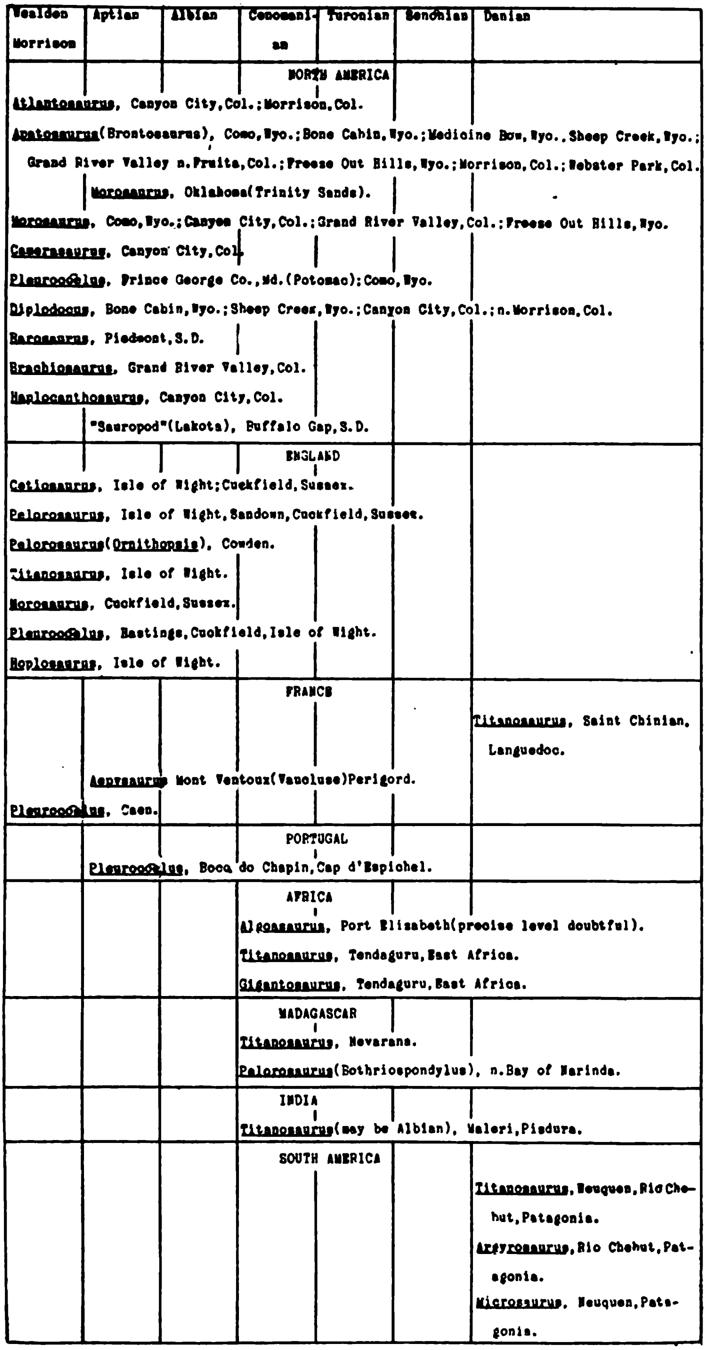
The Sauropoda are abundant in England from the Bathonian (Dogger) to the Wealden, in France from the Bathonian until the Aptian, and then, if Depéret (1899) is right, after a lapse of time during which no Sauropoda left their records elsewhere in the northern hemisphere, they appear again in the form of *Titanosaurus* at Saint Chinian and Languedoc in southern France in beds referable to the Danian—the very close of the Cretaceous period!

In America, with the exception of *Dystrophæus* of the Dogger of Utah and an unnamed Sauropod reported by Gilmore (1909, p. 300) from the Lakota (Aptian) of Buffalo Gap, South Dakota, the Sauropoda are confined entirely to the Morrison and its eastern equivalent, the basal Potomac, and in the South, to the Trinity sandstones of Texas and Oklahoma. A remarkable feature of the career of the American types is that, with the exception of the ill-known *Dystrophæus*, the most generalized *Haplocanthosaurus* and the most specialized *Diplodocus* have been found associated in the same quarry, although Riggs (1904, p. 246) argues for *Haplocanthosaurus* a terrestrial habitat, on account of the similarity in length of fore and hind limb and the apparent inflexibility of the vertebral column; while *Diplodocus* shows the highest degree of aquatic adaptation known within the group.

In the southern hemisphere one finds sauropod remains from India across Madagascar and East Africa to Patagonia, almost the entire length from East to West around the south shore of the old Gondwana continent. There is, however, no record of their occurrence in Australia, a piece of negative evidence which can hardly be weighed heavily in view of the meagerness of the known dinosaur remains in that quarter of our globe.

The principal southern genus is *Titanosaurus* (Lydekker non Marsh), the remains of which are found also in the English Wealden. The beds wherein the southern Sauropods are found are, curiously enough, Upper Cretaceous, probably

FIG. 5.



NORTH AMERICA

Atlantosaurus, Canyon City, Col.; Morrison, Col.

Apatosaurus (Brontosaurus), Como, Wyo.; Bone Cabin, Wyo.; Medicine Bow, Wyo., Sheep Creek, Wyo.; Grand River Valley n. Fruita, Col.; Freeze Out Hills, Wyo.; Morrison, Col.; Webster Park, Col.

Morosaurus, Oklahoma (Trinity Sands).

Morosaurus, Como, Wyo.; Canyon City, Col.; Grand River Valley, Col.; Freeze Out Hills, Wyo.

Camarasaurus, Canyon City, Col.

Pleurocoelus, Prince George Co., Md. (Potomac); Como, Wyo.

Diplodocus, Bone Cabin, Wyo.; Sheep Creek, Wyo.; Canyon City, Col.; n. Morrison, Col.

Barosaurus, Piedmont, S.D.

Brachiosaurus, Grand River Valley, Col.

Haplocanthosaurus, Canyon City, Col.

"Sauropod" (Lakota), Buffalo Gap, S.D.

ENGLAND

Cetiosaurus, Isle of Wight; Cuckfield, Sussex.

Pelorosaurus, Isle of Wight, Sandown, Cuckfield, Sussex.

Pelorosaurus (*Ornithopsis*), Cowden.

Titanosaurus, Isle of Wight.

Morosaurus, Cuckfield, Sussex.

Pleurocoelus, Hastings, Cuckfield, Isle of Wight.

Hoplosaurus, Isle of Wight.

FRANCE

Titanosaurus, Saint Chinian, Languedoc.

Aepysaurus Mont Ventoux (Vaucluse) Perigord.

Pleurocoelus, Caen.

PORTUGAL

Pleurocoelus, Boca do Chapin, Cap d'Espichel.

AFRICA

Algoasaurus, Port Elizabeth (precise level doubtful).

Titanosaurus, Tendaguru, East Africa.

Gigantosaurus, Tendaguru, East Africa.

MADAGASCAR

Titanosaurus, Nevarana.

Pelorosaurus (Bothriospondylus), n. Bay of Narinda.

INDIA

Titanosaurus (may be Albian), Maleri, Pisdura.

SOUTH AMERICA

Titanosaurus, Neuquen, Rio Chehut, Patagonia.

Argyrosaurus, Rio Chehut, Patagonia.

Microsaurus, Neuquen, Patagonia.

FIG. 5. Distribution of the Cretaceous Sauropoda (original).

FIG. 6.

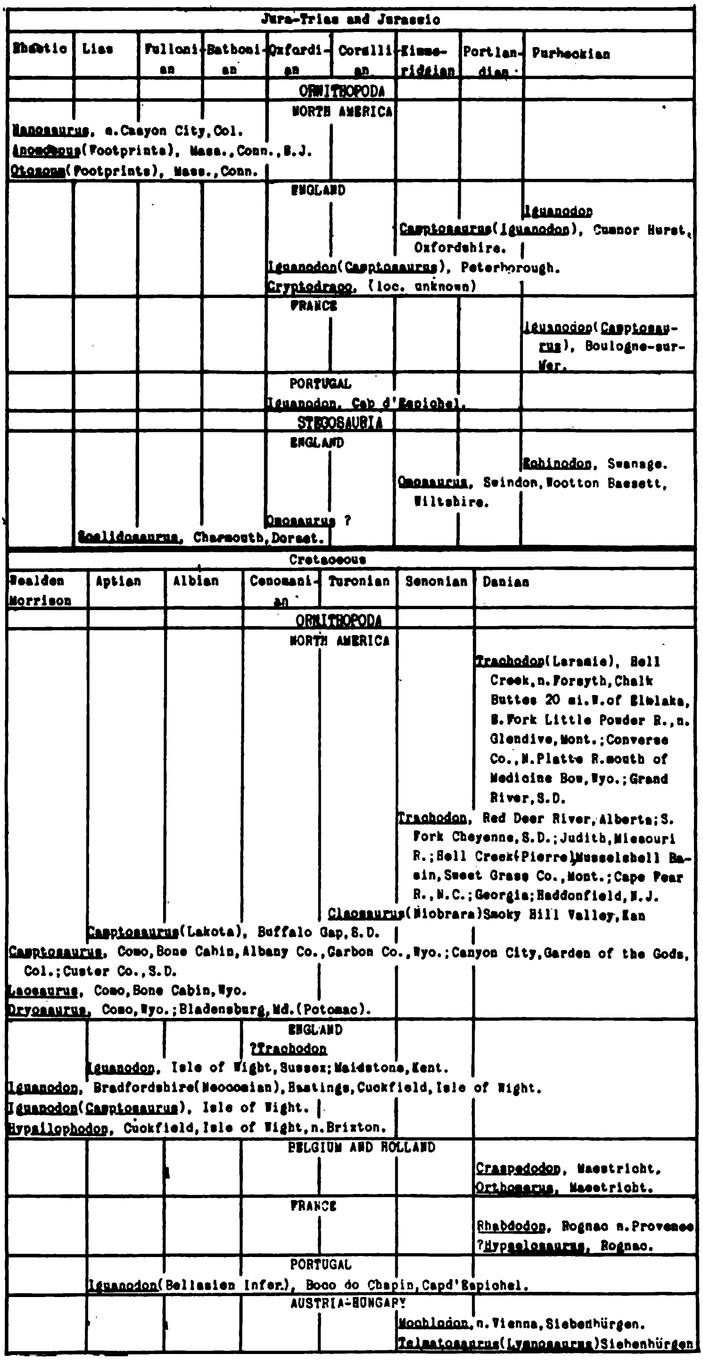


FIG. 6. Distribution of the Jura-Trias and Jurassic Orthopoda and of the Cretaceous Ornithopoda (original).

not older than Cenomanian time, and, with the exception of the questionable *Macrourosaurus* of the English Cenomanian and the *Titanosaurus* reported by Depéret (vide supra) from the Danian of Southern France, the contained dinosaurs represent by far the latest appearance of the Sauropod group anywhere recorded on the face of the globe.

The last stand of these huge creatures, so far as our present knowledge goes, and again excepting Depéret's *Titanosaurus* (vide supra, p. 26), was in Patagonia, where the remains of three genera, *Titanosaurus*, *Argyrosaurus* and the small aberrant *Microsaurus* are found in the Guaranitic beds correlated by Hatcher (1900, p. 95) with the Laramie (Danian) of North America.

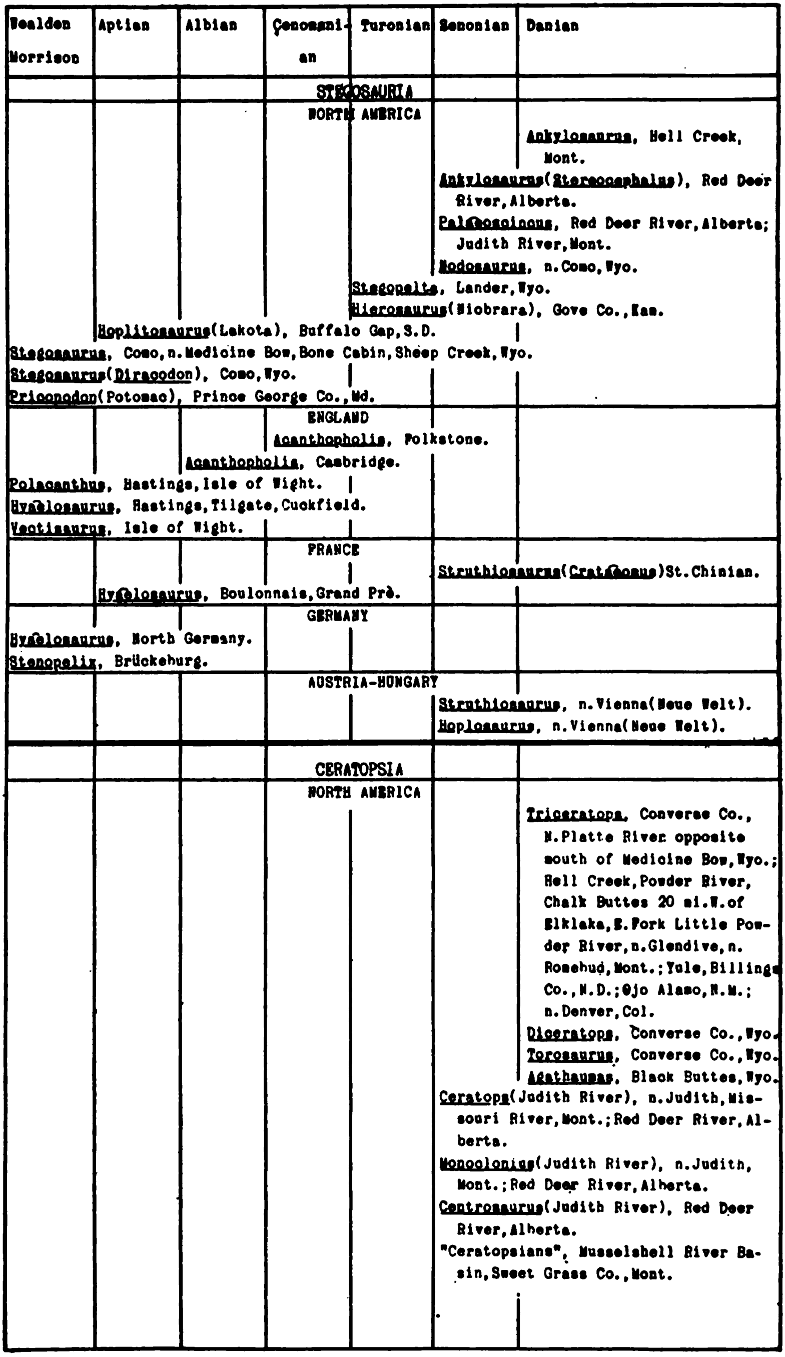
Orthopoda.

Geographically the Orthopoda (figs. 6 and 7) as a whole, with the exception of the Ceratopsia, which are apparently confined to western North America, have a common distribution; and, while paralleling that of the other dinosaurs in the northern hemisphere, are unique in their entire absence from the southern. It can hardly be said that the paucity of our records is responsible for this apparent lack of southern forms, for their preservation and discovery should surely have brought some to light when the Theropoda and Sauropoda are relatively so abundant.

America seems to have been the original home of the orthopod dinosaurs, the first recorded type the bones of which are known being *Nanosaurus* of the Jura-Trias of Utah. In the upper series of the Newark (Rhætic) beds in Massachusetts, Connecticut and New Jersey are indications of numerous species of these plant-feeding forms, so that it is evident that by the beginning of Jurassic time not only were they widespread in North America but they had reached a considerable degree of variation as well, implying a long though unrecorded career. During the Jurassic the record is again a blank as with the American Theropoda, but with the ushering in of Lower Cretaceous time by the great Morrison deposits in the West and the Potomac in the East we find a marvelous assemblage of types, small and large, armored and unarmored. This is especially true in the West, since the Potomac dinosaurs, coming as they do from few localities which are all of one character, reflect the Sauropod rather than the Orthopod habitat, so that while an armored dinosaur, *Priconodon*, and an unarmored *Dryosaurus* (Lull 1910) only have been found in Maryland, others doubtless existed and may some day be brought to light.

All through Upper Cretaceous time the American record is quite complete, especially in the West, though New Jersey,

FIG. 7.



Wealden Morrison | Aptian | Albian | Cenomanian | Turonian | Senonian | Danian

STEGOSAURIA

NORTH AMERICA

Ankylosaurus, Hell Creek, Mont.
Ankylosaurus(*Stereocephalus*), Red Deer River, Alberta.
Palæoscincus, Red Deer River, Alberta; Judith River, Mont.
Nodosaurus, n. Como, Wyo.
Stegopelta, Lander, Wyo.
Hierosaurus(Niobrara), Gove Co., Kan.
Hoplitosaurus(Lakota), Buffalo Gap, S.D.
Stegosaurus, Como, n. Medicine Bow, Bone Cabin, Sheep Creek, Wyo.
Stegosaurus(*Diracodon*), Como, Wyo.
Priconodon(Potomac), Prince George Co., Md.

ENGLAND

Acanthopholis, Folkstone.
Acanthopholis, Cambridge.
Polacanthus, Hastings, Isle of Wight.
Hylæosaurus, Hastings, Tilgate, Cuckfield.
Vectisaurus, Isle of Wight.

FRANCE

Struthiosaurus(*Cratæomus*) St. Chinian.
Hylæosaurus, Boulonnais, Grand Prè.

GERMANY

Hylæosaurus, North Germany.
Stenopelix, Brückeburg.

AUSTRIA-HUNGARY

Struthiosaurus, n. Vienna (Neue Welt).
Hoplosaurus, n. Vienna (Neue Welt).

CERATOPSIA

NORTH AMERICA

Triceratops, Converse Co., N. Platte River opposite mouth of Medicine Bow, Wyo.; Hell Creek, Powder River, Chalk Buttes 20 mi. W. of Elklake, E. Fork Little Powder River, n. Glendive, n. Rosebud, Mont.; Yule, Billings Co., N.D.; Ojo Alamo, N.M.; n. Denver, Col.
Diceratops, Converse Co., Wyo.
Torosaurus, Converse Co., Wyo.
Agathaumas, Black Buttes, Wyo.
Ceratops(Judith River), n. Judith, Missouri River, Mont.; Red Deer River, Alberta.
Monoclonius(Judith River), n. Judith, Mont.; Red Deer River, Alberta.
Centrosaurus(Judith River), Red Deer River, Alberta.
"Ceratopsians", Musselshell River Basin, Sweet Grass Co., Mont.

FIG. 7. Distribution of the Cretaceous Stegosauria and Ceratopsia (original).

North Carolina and Georgia have yielded Trachodons of Magothy (Senonian) age.

The great culmination of the group, in which the older types were joined by the remarkable Ceratopsia, occurred toward the close of the Cretaceous in the area lying just eastward of the Rocky Mountains and extending from New Mexico on the south to Alberta on the north, perhaps beyond.

In the Old World I have searched in vain for traces of Orthopoda before the Lias. Beasley, Sollas and others have described many fossil footprints from beds ranging from the Bunter to the Upper Keuper, including some undoubted dinosaurian tracks (Sollas 1879, pp. 511–516) resembling those of *Anchisauripus* (*Brontozoum*, part) (Lull 1904, p. 486) of the Connecticut formation. There is none among them in any way comparable with *Anomœpus* (Lull 1904, p. 500) of the New World. Beasley (1907, p. 167–168) is inclined to think that he has in *Chirotherium storetonense* from near Liverpool the footprint of an herbivore. That one may readily consent to, but the foot in no way resembles that of a dinosaur and the tracks are generally referred to unknown labyrinthodonts.

In the English Lias the first Orthopod appears in the form of the armored *Scelidosaurus* followed in the Oxfordian by *Omosaurus* and later by *Echinodon*. Recorded specimens of armored forms are entirely confined to England during Jurassic time and not until the Wealden do we find their remains on the continent. With the Cenomanian they apparently forsake their earlier home entirely for the continent, culminating in *Struthiosaurus* and *Hoplosaurus* of Austro-Hungary and southern France.

The unarmored Orthopoda, the Ornithopoda, begin their Old World career simultaneously in England and Portugal in beds of Oxfordian age, but are not numerous during the Jurassic. The Wealden, however, brings in a great many species, some in wonderful preservation. Their subsequent history is much like that of the armored types, culminating in Austro-Hungary, France and Belgium.

It will be observed that no mention is made of the Asian continent north of India—the ancient Angara-land. Thus far our records show absolutely no trace of dinosaurian remains from any part of this vast area. Professor Marsh (1897, pp. 413–414) says: "In St Petersburg I hoped to find many dinosaurian remains, as here had been brought together an abundance of fossil treasures from various parts of the Russian Empire, which I knew must contain many forms of this group. In the four principal museums of the city, however, I could find no bones of Dinosaurs on exhibition, nor could I learn from any of the museum authorities that such remains had

Fig. 8.

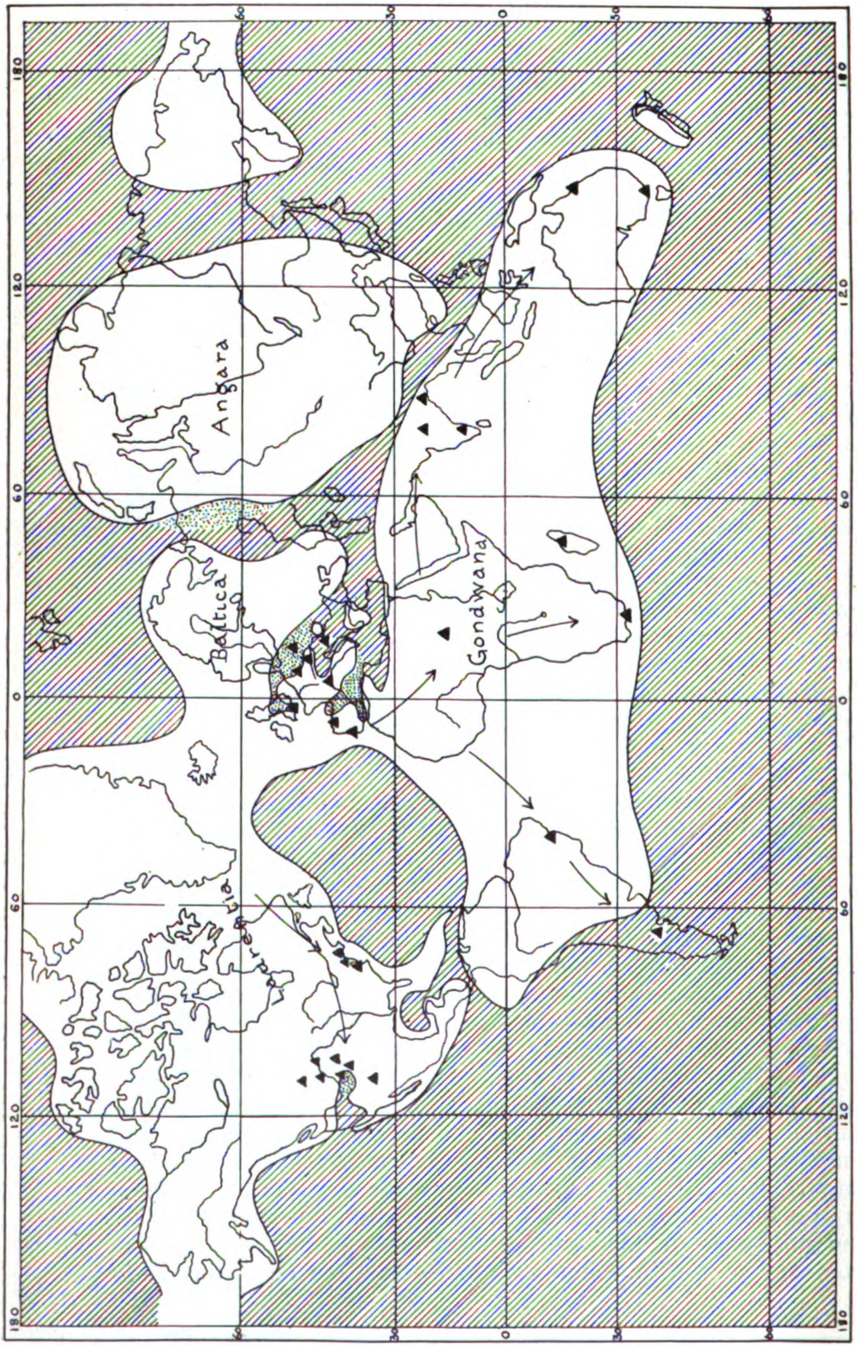


Fig. 8. Map showing the principal localities of the Theropoda with probable routes of migration. Based upon the lower Triassic maps of Schuchert for North America and de Lapparent for the rest of the world. (Dotted areas, terrestrial deposits.)

Fig. 9.

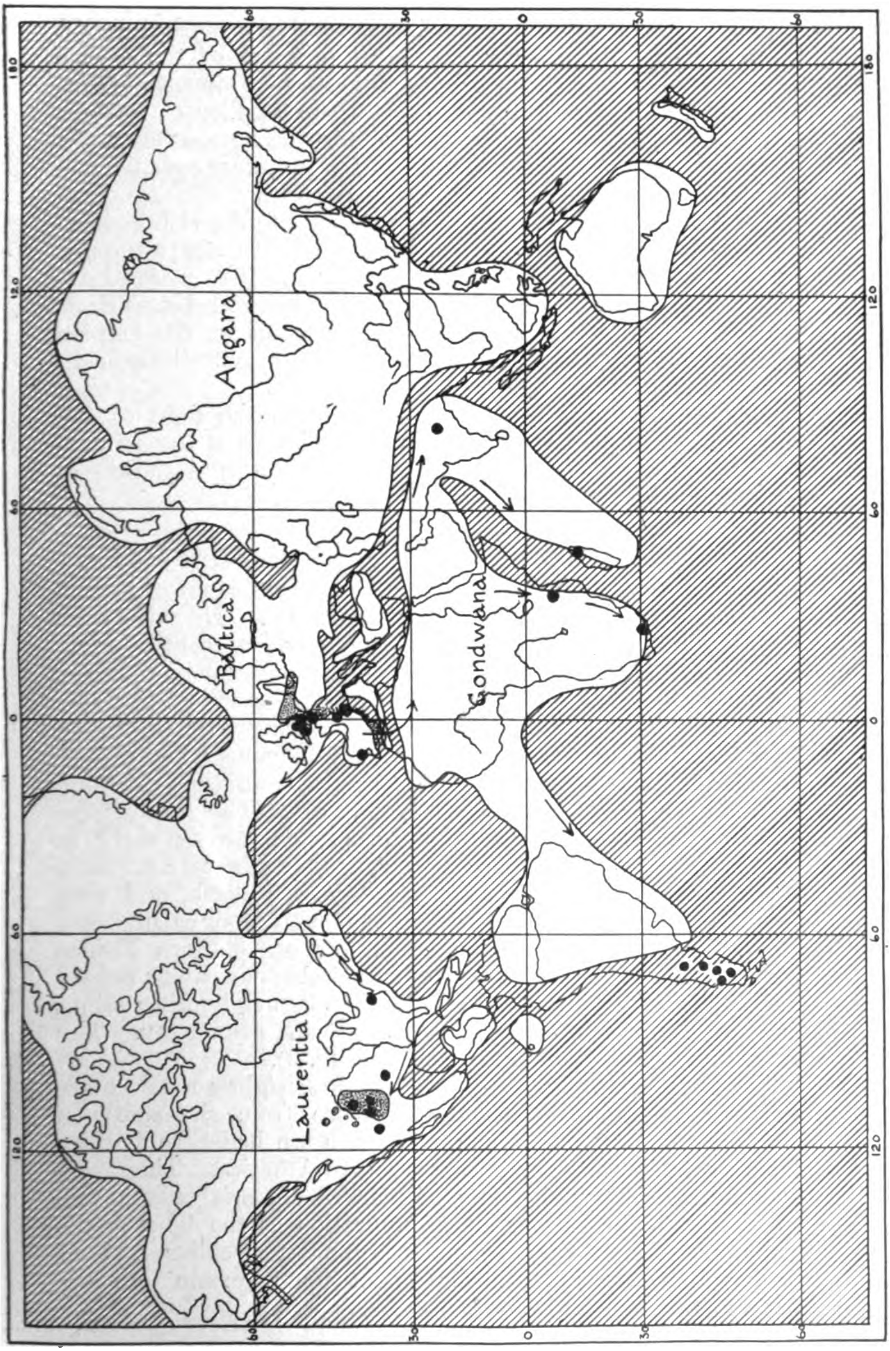


Fig. 9. Map showing the chief localities and probable routes of migration of the Sauropoda. Based upon Schuchert's late upper Jurassic map of North America and de Lapparent's Wealden map for the rest of the world.

been recognized among the specimens received, neither could I find any such fossils myself among the debris of the collections, so often a rich repository for new or inconspicuous specimens. This was true, also, of the smaller collections visited, and I was at last forced to admit that here, at least, the Dinosaurs of Russia like the snakes of Ireland, were conspicuous only by their absence.

"This opinion was not changed by a visit to the rich geological collections of Moscow, which I examined with care; although other fossil vertebrates, including many reptiles, were abundantly represented. I was assured, moreover, by various Russian paleontologists, that in other museums of the empire or in the known localities they had seen no dinosaurian remains."

This evidence can be interpreted again in the light of the fact that Asia is so largely a *terra incognita* from the paleontologist's point of view, or in that of the physical isolation of Angara during the whole dinosaurian epoch.

VI. SUMMARY OF MIGRATIONS AND PALEOGEOGRAPHY.

The probable center of evolution and course of migration of the Theropoda has already been sketched. Having their origin apparently somewhere in the northern continent of Laurentia, they deployed southward and westward, covering not only the confines of western Europe but extending into Gondwana, the southern land mass, during Triassic times. New Zealand they never reached and they may have been retarded in their passage to South America until the beginning of the Lower Cretaceous (see fig. 8). The Sauropoda probably had their origin in Europe, migrating early in Jurassic time to the southern as well as to the western continent. Thence in the southern hemisphere both east, south, and west until their range was almost as great as that of their carnivorous allies. Whether the Danian Titanosaur of southern France was a returned migrant or whether suitable conditions caused it to linger long after the death of all of its neighboring allies, like the Steller's sea cow in Behring Sea, I cannot say. The second idea seems the more probable (fig. 9).

The Orthopoda (fig. 10) present at first sight a much more serious difficulty in their entire absence from the southern hemisphere. It would seem as though we had here a group the center of whose dispersal was North America. They were truly terrestrial types, many of marked cursorial adaptation, which should be as capable of migration as the Theropoda. They were, however, dependent upon a peculiar sort of food which was in turn dependent upon certain climatic

FIG. 10.

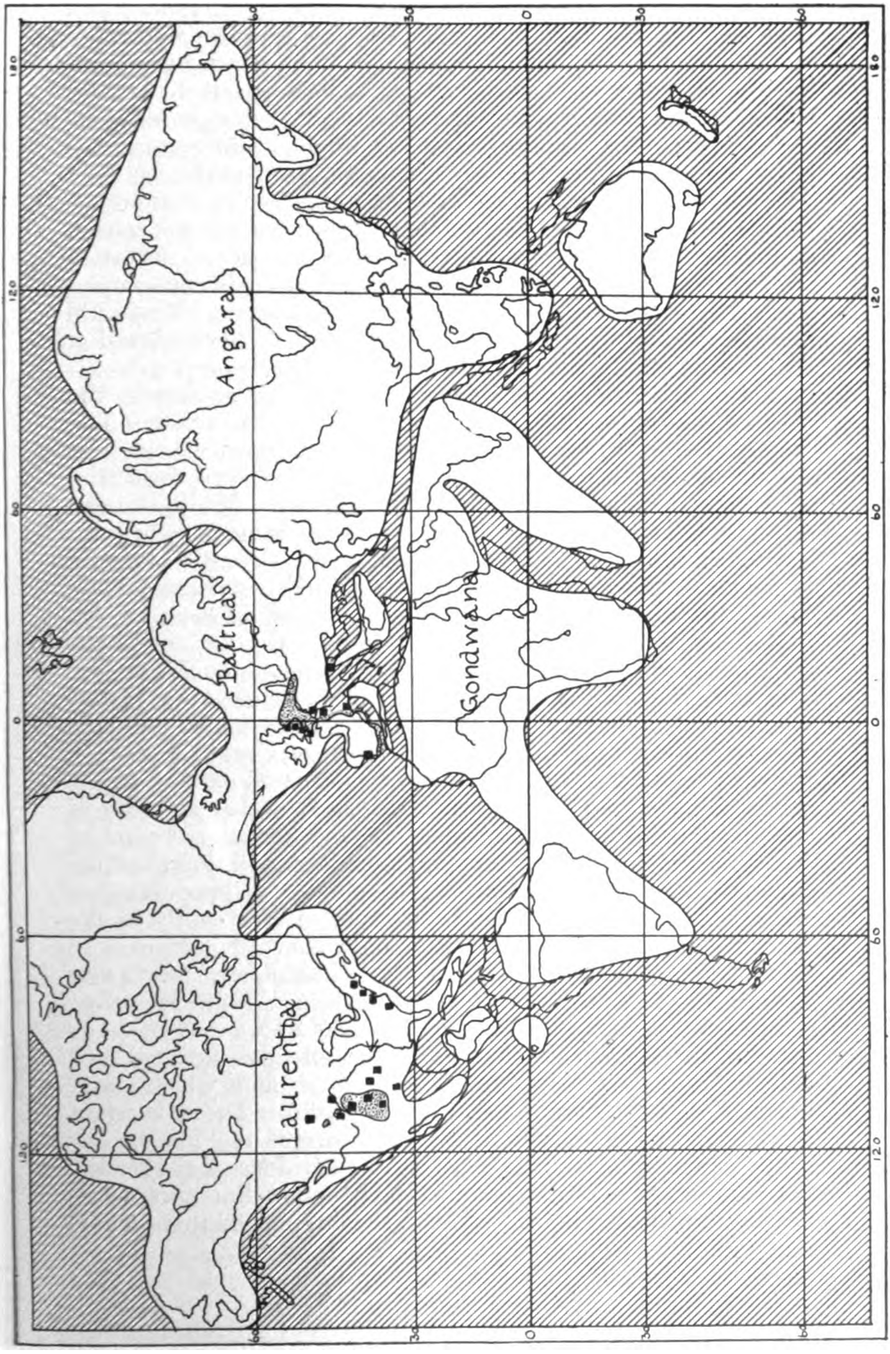


FIG. 10. The same map as in fig. 9, showing localities and migratory routes of the Orthopoda.

conditions and necessarily went where food was abundant and were checked where it failed. The opportunity for migration to Gondwana Land from Europe by a dry land route may readily have ceased before the Orthopoda reached the Old World. The Sauropoda, on the other hand, being amphibious could cross broken land connections provided the water were not of too great an extent. It is a significant feature that only Theropods, Sauropods and the late Cretaceous Orthopods, *Claosaurus* and *Trachodon*, have been found in marine deposits, indicating a semi-aquatic life on the part of the latter two and at least a fearlessness of water when necessity arose upon that of the carnivores. By the time the Trachodont dinosaurs reached the Old World the opportunity for southern migration even for an amphibious animal had apparently ceased.

A comparison may well be made with living mammals, the deer on the one hand, the hippopotamus on the other. The former are world-wide in their distribution except for Australasia, the Arabian peninsula and Africa, save for a single species, *Cervus barbarus*, which inhabits the Mediterranean coast from Tunis to the slopes of the Atlas range. Schillings (1906, p. 261) says: "In 1896 hippopotamuses were still plentiful in the Nzoia River and the Athi River in British East Africa; they were to be found, too, along the coast between Dar-es-Salaam and Pangani. I saw them on several occasions in the surf, and I shall never forget my astonishment once, on getting out of a clump of cocoanut palms, to see what I had imagined to be an uprooted tree trunk on the sands suddenly change into a hippopotamus and make its way into the sea.

"Hippopotamuses travel by sea to get from one estuary to another, no doubt ridding themselves at the same time of certain parasites in the salt water."

Hippopotamuses show no more aquatic adaptation than the sauropod dinosaur, *Diplodocus*, if as much. Hippopotamuses are confined in their present range to Africa south of the Sahara, being found in the Nile only above Khartum. In former times they extended to Madagascar, northwest India and practically the whole of western Europe including southwest England (Murray 1866, map XXIX). This shows that certain barriers exist which prove effective against such extremely mobile creatures as the deer and which have debarred them from the Ethiopian realm. These barriers, however, were not prohibitive in the case of the less mobile hippopotamus. A similar contrast of conditions might readily have limited the distribution of the Orthopod dinosaurs, while the Sauropoda, as in the case of the hippopotamuses, could easily migrate.

Why the Sauropoda lingered so long in the southern hemisphere after their apparent extinction in the North, is difficult to answer unless it were because of the limitations of food and climate in the North which did not at once prevail in the South. Even though the Trachodontidæ gradually assumed aquatic habits, they were too late to be brought into active competition with the Sauropoda in the northern land mass.

The carnivores being always present doubtless served at first only to limit the plant-feeding forms; they may, however, have been responsible for the final blotting out of the Sauropoda when weakened in numbers and by the burden of racial old age.

I believe that, all things considered, the degree of moisture, whether atmospheric in accelerating or limiting plant growth, or in the form of actual water barriers, was the most potent factor in the origin, evolution, migrations, and final extinction of the dinosaurian race.

Williston (1909, p. 401) is inclined to think that "there must have been free communication during part or all of the Mesozoic time between North and South America, proof of which is seen in the dinosaurs, mosasaurs, and crocodiles, some of them being, according to competent observers, identical generically even with North American forms." This may be true of the crocodiles and mosasaurs and yet imply no land bridge over which dinosaurs could pass. True, fragmentary remains from Patagonia have been referred to *Allosaurus* so characteristic of the American Morrison, but I seriously question the generic identity of any of the dinosaurs with North American forms. The presence of the earliest recorded remains near Bahia, on the line of march from the East, may be taken at its apparent value. I have found no evidence in favor of a north and south migration in the western hemisphere.

These studies only serve to verify for the most part the paleogeographical maps of de Lapparent and Schuchert, for in every instance, with the exception of Patagonia and where the dinosaur was found in salt water deposits, the locality fell upon a land area as indicated upon the maps. I would, however, differ from de Lapparent in his inclusion of New Zealand in the Gondwana continent after the beginning of the Trias. The finding of similar dinosaurs on either side of the Mozambique Channel during the Cenomanian, after the cleavage of Gondwana Land into an Indo-Madagascar and an Africo-Brazilian mass, has been explained by Depéret (1909, p. 303), who assumes that a temporary closure of the gap occurred. As the Madagascar types are mainly Sauropod, one of which was found associated with *Mytilus* and Foraminifera, the closure may not have been complete. It is not, however, necessary to assume even a partial closure, as my map (fig. 9) will show. De Lapparent's maps show no connection between Gondwana Land and Patagonia until the Basal Eocene, which is too late for the migration of the Patagonian (Danian) dinosaurs from the northeast. The closure may have occurred not long before, however, so far as dinosaurian evidence is concerned.

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Art. II.—*The Origin of the Crinoidal Muscular Articulations*; by Austin Hobart Clark.

The peculiarly complicated type of muscular articulation by which the post-radial ossicles of the crinoids are joined together is generally supposed to have been derived from the so-called loose suture, the connective tissue of which has gradually become differentiated into two different types of ligaments and also into true muscle. The steps by which this process has come about have never been satisfactorily shown.

While there appears to be in the crinoids a direct continuity between the connective tissue through various types of ligamentous attachment to true muscle, yet it does not seem probable that the differentiation of the connective tissue between two adjacent ossicles could ever have progressed so far as to produce the conditions found in the crinoids, where two bundles of highly specialized muscle fibers occur, histologically, as well as in their location, sharply differentiated from the ligaments.

A comparison of the crinoids with the two most nearly related recent classes, the Echinoidea and the Holothuroidea (Bohadschoidea), offers, however, an easy solution of the problem of the origin of the complex crinoidal muscular articulations.

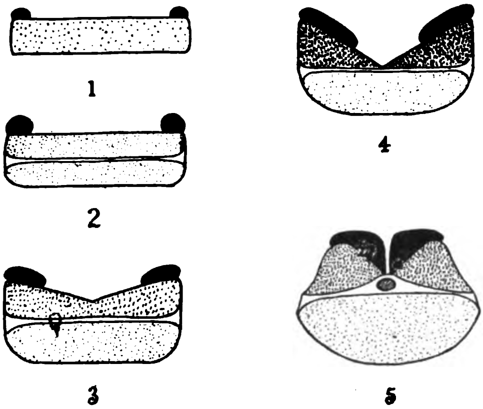
In the Echinoidea the plates are united more or less closely by connective tissue, just as are the interradials and the secondary perisomic plates generally in the recent crinoids, and this was probably the original mode of union for the primary ambulacral ossicles of the crinoids as well. Now in all the heteroradiate Echinodermata (which include the Pelmatozoa, Echinoidea, and Holothuroidea) wherever the ambulacral ossicles or body wall are at all flexible, as occurs in the crinoids, in the holothurians, and in the echinothurids among the echinoids, each ambulacrum possesses a pair of longitudinal muscles one of which runs along either outer border, and may extend itself more or less inward. No definite homology has ever been proved between these five longitudinal ambulacral muscle pairs which are so constant in all the recent heteroradiate Echinodermata possessing the possibility of ambulacral motion; but from the uniform presence and location of these muscles it seems most probable that such homology actually exists.

Now if the ancestral crinoids possessed a longitudinal muscle along each border of the ambulacral series, as we must infer from analogy with the echinothurids and the holothurians, their closest recent relatives, we may assume an ambulacral structure something like that of the former—a series of ambulacral ossicles united by connective tissue with a longitudinal muscle band running interiorly along either side of the ambulacral series as a whole. It is easy to imagine that at first the muscle bands were fanlike in arrangement and broad as in the echinothurids, but later, with increased flexibility of the test, became narrow, and finally resolved themselves into longitudinal muscles more like those of the holothurians. With increased scope of motion between the ambulacral ossicles, beveling was induced, whereby the apposed faces of adjacent ossicles were in close apposition in the median line (perpendicular to the line between the center of the ossicle and the center of the calyx) but sloped away from each other both inwardly and outwardly. The connective tissue along this median line, the prototype of the so-called transverse ridge, now became very short and dense, forming what is practically a very narrowly linear close suture; while the connective tissue on the remainder of the articular surfaces was more or less lengthened, and gradually became ligamentous in nature, at the same time, through the separation of the internal edges of adjacent ossicles, the longitudinal muscle bands were, by pressure from within the calyx, pushed in between them, and certain of the fibers came to be inserted on the apposed faces of the ossicles instead of only on the ventral (interior) surface. This would give the ambulacral ossicles a joint face consisting of two equal oblong ligament fossæ, separated by a narrow transverse ridge, with a small muscular fossa at each outer corner of the inner ligament fossa. Now the calyx of the crinoids is remarkable for its very small size, and hence in the development of the race we may assume that this decrease in size has caused it to press more or less upon the internal organs. This pressure would not be equal at all points on the inner surface of the ossicles because of the existence of various radial vessels which run along the center of the ambulacra, chief among which is the axial nerve cord. These vessels would, by this pressure, encroach upon the area of the inner ligament fossa, and would tend to excavate it in the form of a more or less broad V, at the apex of which would be the axial nerve cord; at the same time the muscles would encroach more and more upon the articular face, and the part of the original muscular band which originally ran along the inner side of each individual ossicle, having now become useless, would disappear. The ventral ligament fibers, as a result of the decrease in the area of the fossa occupied by them through the encroachment of the "soft parts," not being able to migrate past the close suture along the transverse ridge, would come to lie more and more closely together, and would form two masses each more dense and compact than that of the outer (dorsal) ligament mass, which remains unchanged. The muscles, unable to penetrate into the area occupied by the two resultants from the originally single inner (ventral) ligament mass, would gradually creep inward along their outer edge toward the center of the joint face. When the encroachment of the "soft parts" had progressed so far as to cause the axial nerve cord to lie upon the transverse ridge, we would find a condition as follows: first a large undivided dorsal ligament fossa occupied by more or less scattered contractile ligament, and bounded ventrally by the transverse ridge; just ventral to the transverse ridge would be found two triangular fossæ, one on either side, lying with their apices just under the center of the axial cord and one of their sides coinciding with the transverse ridge; these fossæ would lodge ligament masses similar to the dorsal ligament mass, but much more dense; on the outer distal corners of each of these two triangular fossæ would be found muscular fossæ, which would extend more or less inward toward the center of the joint face, but which would never meet in the median line. Thus we have arrived at the type of muscular articulation characteristic of the crinoid arm, comprising a single dorsal ligament fossa, two interarticular muscular fossæ, and two ventral muscular fossæ. This theory of the genesis of the crinoidal muscular articulations (1) explains the peculiar deneness of the interarticular ligament masses, and (2) does away with the necessity of assuming that the muscles are the specialized connective tissue of an original loose suture.

I have already shown how the peculiarly modified non-muscular articulations, the syzygy and the synarthry, are derived from the muscular type of articulation; so that now we are enabled to derive every known type of union between the ossicles of the crinoid crown from the simple connective tissue union known as the loose suture.

A few words in regard to the syzygy may not be out of place. Minckert, like all his predecessors except Sars, believes that the syzygies are joints of especial weakness in the crinoid arm where fracture takes place in case the arm is seized, due to this especial weakness. He also believes that in adolescent autotomy the arm is voluntarily cast off by the animal at the first syzygy. My experience with living crinoids has led me to agree with Sars; the syzygy is at least as strong as the muscular articulations, as anyone may prove for himself by breaking up crinoid arms. Under certain conditions, however, the syzygy becomes peculiarly weak, and often breaks of itself. I believe that this is susceptible of ready physiological explanation. Bosshard has shown that the fibers of the dorsal ligament and of the syzygy are histologically the same, the only difference being that the latter are extremely short. Now since the fibers of the dorsal ligament and of the syzygy are identical except in length, we should expect that they both would possess the same physiological characteristics, and, therefore, that the fibers of the syzygy would be contractile in the same way that those of the dorsal ligament are, though their possible loss or gain in length, owing to their shortness, would be very slight. As the fibers of the syzygy are continuous in substance through the organic base of the ossicles with those of the dorsal ligaments preceding and succeeding, it is probable

Figs. 1–5.



Diagrams illustrating the origin of the muscular articulations of Crinoids.

Fig. 1. The primitive joint face, with connective tissue binding; the two longitudinal ambulacral muscles are seen on the outer angles.

Fig. 2. A joint face differentiated by the development of a transverse ridge; the connective tissue on either side has become ligamentous, and the muscles have increased in size.

Fig. 3. A joint face showing reduction of the internal fossa by pressure of the "soft parts;" the ligament of the internal fossa is becoming denser; the muscles have increased in size.

Fig. 4. The internal fossa has now become divided into two interarticular ligament fossæ, lodging dense ligament bundles; the muscles have become still larger.

Fig. 5. Radial face of one of the Zygometridæ.

that they act in sympathy with them, expanding and contracting, in their small way as they do. It may be readily supposed that the tension of the fibers in the syzygy is adjusted to the ordinary movements of the crinoid arm. The dorsal ligaments are normally always antagonized more or less by the powerful ventral musculature and ordinarily never contract to their furthest capacity. If for any reason the ventral muscles are rendered inert, as by the panic incident to capture, then the dorsal ligament would contract to the farthest limit, and the fibers in the syzygies, through sympathetic action, would also contract, but, being normally under more or less tension, would not be able to take up this contraction within themselves, but would be pulled apart, thus breaking off the arm at the syzygy. Fracture of the arms at the syzygies, then, would appear to be an entirely involuntary act on the part of the crinoid, due solely to the physiological effects of panic; this panic may, of course, be more or less general, or localized, so that stimulus of the calyx would induce fracture at the first brachial syzygy, stimulus on the arms at the neighboring syzygies.

During the growth of most of the oligophreate comatulids the ten original arms are cast off, often at the first syzygy, and from the stumps axillaries arise bearing several arms. Minckert supposed that this was a voluntary action; but it is noticeable that all the comatulids which have more than ten arms have short brachials which are correlated with a corresponding shortness in the muscle fibers and dorsal ligament fibers uniting them. Now it seems probable that during growth the dorsal ligament fibers are able to accommodate themselves gradually to their decreasing length through their contractile power; but this would have exactly the same effect upon the syzygies as panic—they would be torn apart—so that the casting off of the arms of the ten armed young of the oligophreate comatulids appears to be, not a voluntary action, but a direct result of the gradual change from the juvenile to the adult type of brachial.

ART. III.—*On the Substitution of Bromine and of Iodine for Chlorine in the Separation of Cerium from the other Cerium Earths;* by PHILIP E. BROWNING and EDWIN J. ROBERTS.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccvi.]

ONE of the best known processes for the separation of cerium from lanthanum and didymium is that of Mosander.* This process consists in passing chlorine gas into a mixture of the hydroxides suspended in a distinct excess of a fixed alkali hydroxide, until the solution is saturated and the reaction of the liquid is no longer alkaline to litmus. Under these conditions nearly all the cerium remains undissolved as the ceric hydroxide, while the other cerium earths go largely into solution. In treating mixed material the residue of ceric hydroxide generally retains some of the cerium earths so that the treatment with chlorine must be repeated. Two disadvantages associated with this method therefore are, the preparation and use of chlorine gas, and the solvent action of the hydrochloric acid formed in the reaction upon the ceric hydroxide

$$2Ce(OH)_3 + Cl_2 = 2CeO_2 + 2HCl + 2H_2O.$$

The work to be described was undertaken to study the effect of substituting bromine or iodine for chlorine in this process. A preliminary experiment was made by suspending a precipitate of the washed hydroxides of the cerium earths in water, adding a little liquid bromine, and allowing the action to go on for several hours with occasional stirring. The precipitate took on the color of the ceric hydroxide, and on filtering the filtrate was found to contain a considerable amount of cerium earths free from cerium.

In the following experiments solutions of known amounts of the mixed oxides, composed of about 50 per cent of cerium and 50 per cent of the cerium earth oxides other than cerium, were treated with a slight excess of sodium or potassium hydroxide. To these hydroxides suspended in the alkaline solution, liquid bromine or bromine water was added in distinct excess, and the mixture was placed upon a steam bath until the greater part of the free bromine was expelled. The residue was then filtered off, washed, and treated as before. This process was repeated twice, and the filtrate after each treatment was found to contain the amounts of cerium earth oxides, free from cerium, indicated in the table. The residue from the last treatment on being dissolved in acid showed only faint didymium bands. In experiment (6) the indication of the presence of didymium was very faint. In another experiment the same amount of material used in (5) and (6), 10 grams, was subjected to a fourth and fifth treatment with bromine, the fourth treatment yielding a small fraction of a gram of the oxides, and the fifth only a few milligrams. In both cases these oxides were free from cerium. The oxides from the first filtrates were much lighter in color than those obtained from the last, which, of course, indicates that the lanthanum is dissolved by the action of the bromine more readily than the didymium. The results follow in the table:

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* J. prakt. Chem., xxx, 267.

	Mixed oxides taken grm.	**Oxides found in first filtrate** grm.	**Oxides found in second filtrate** grm.	**Oxides found in third filtrate** grm.	**Total oxides found** grm.
(1)	1·0000	0·3310	0·0720	0·0190	0·4420
(2)	1·0000	0·2900	0·1010	0·0420	6·4330
(3)	1·0000	0·2250	0·1290	0·0640	0·4180
(4)	1·0000	0·2750	0·0860	0·0740	0·4350
(5)	10·0000	3·1360	1·0050	0·5930	4·7340
(6)	10·0000	3·4590	0·5240	0·8560	4·8390

So it has been shown that by substituting bromine for chlorine in the Mosander process about 50 per cent of the other cerium earths can be separated from ceric hydroxide in one treatment, and that after three treatments practically all the other cerium earths are removed without any solvent action upon the ceric hydroxide. The advantages of the method are, the convenience in the use of the bromine, and the apparent lack of tendency of the hydrobromic acid to dissolve the ceric hydroxide.

An experiment was made, using iodine in place of bromine, as follows: The precipitated and suspended hydroxides from 2 grams of the mixed oxides were treated with 1 gram of solid iodine. After standing for about two hours on a steam bath, the excess of iodine was removed by boiling, and the residue of hydroxides was filtered off. The filtrate gave 0·0980 grm. of oxides, free from cerium, and of a slight brown color. This shows that the action of iodine is the same, in a general way, as that of chlorine and bromine, but is too incomplete to be of any practical value.

Art. IV.—*New Fossil Coleoptera from Florissant, with Notes on some already described;* by H. F. Wickham.

Calosoma Web.

C. cockerelli n. sp. A piece of a wing cover lacking both base and apex is referred to this genus. It represents a species about the size of *C. calvini* m., from the same shales. The elytron is marked with sixteen well impressed punctured striæ, besides an indeterminate number (perhaps two) closer to the outer margin. The interspaces are nearly four times as wide as the diameter of the punctures in most parts of the area, but in the neighborhood of the apex of the tenth and eleventh striæ the punctures are much larger than elsewhere and are equal in diameter to the interstitial width. In general, the punctures are rounded or slightly elongate and they are separated longitudinally by spaces about equal to their own diameters. The elytral surface shows no indication of the coarse imbricate scabrosity of the interstrial spaces which is evident in our recent North American *C. calidum*, nor are any series of interstitial punctures visible. The interspaces are apparently slightly convex. Length of fragment about 9·25^{mm}, greatest width 6·15^{mm}.

Station number not given. Collection number 232, Florissant Expedition 1906. Received from Prof. Cockerell. Holotype in Peabody Museum of Yale University. Cat. No. 10.

Pterostichus Bon.

P. pumpellyi Scudder. An elytron showing obverse and reverse is referred here with fair certainty. The elytral striæ are nine in number and are more clearly exhibited on the reverse. They are fine, sharp, fairly deep, perfectly smooth, the interspaces moderately convex. The scutellar stria joins the first at about 1·75^{mm} from the base. Length 9·75^{mm}, width 3·40^{mm}.

Station number 13. Collection number, obverse 87, reverse 65, Florissant Expedition 1906. Received from Prof. Cockerell.

Platynus Bon.

A specimen in obverse and reverse, believed to belong to this genus, is among the material sent by Prof. Cockerell. The elytra are 6·20^{mm} in length, and have a conjoint width of 4·10^{mm} at middle. They are finely striate, about as in our recent *P. placidus*, and are apparently almost or quite impunctate. Compared with *P. tartareus* Scudder, from the Florissant shales, the specimen in hand has the humeral angles less rounded and the elytral apices decidedly less truncate. The remainder of the body is too poorly preserved for study, and it seems scarcely wise to impose a specific name.

Station number 13a. Collection numbers 114 and 155, Florissant Expedition 1906. Collected by Mrs. W. P. Cockerell, and received from Professor Cockerell. Specimen in the Peabody Museum of Yale University, Cat. No. 11.

Peltis Illiger.

P. laminata n. sp. Form oblong-elliptical, similar to that of the recent North American *P. pipingskældi.* Head larger than in that species, somewhat dilated by pressure. Prothorax, as preserved, broader shortly in front of the base, sides arcuately narrowed to apex which is broadly emarginate, front angles a little greater than right, hind angles obscure but apparently obtuse and rounding, a faint basal marginal line somewhat as in Colorado specimens of the recent *P. ferruginea.* Elytra slightly broadest at base, where they are a little wider than the prothorax, scarcely perceptibly narrower to a point behind the middle, thence rapidly arcuately narrowed to the apices, which are nearly pointed and (through distortion) dehiscent. The disk shows traces of having been finely striate but the sculpture of the entire surface is now scabrous and obscure. The sexual organs are protruded from the tip of the body but show no definite structure. Length, including extruded sex organ, 12·50^{mm}; of prothorax along median line, 2·25^{mm}; of elytra, 6·60^{mm}; width of prothorax, 5^{mm}; of elytra conjoined, 6·25^{mm}.

In outline, this insect quite closely recalls several recent species of *Peltis*, though the form of the thorax is slightly nearer that of *Calitys scabra.* However, the thoracic and elytral margins are perfectly clear-cut and entire as in *Peltis*, while in our *Calitys* they are coarsely serrate. The antennæ and legs are not shown.

Station number R. 4. Collection number 145, Florissant Expedition 1906. Received from Prof. Cockerell. Holotype in the Peabody Museum of Yale University, Cat. No. 12.

Atænius Harold.

A. patescens Scudder. One specimen, in reverse, exceeding Scudder's measurements by about ·50^{mm}, is included in the collection. The state of preservation is only fair and no important characters can be added to the original description.

Station number 14. Collection number 207, Florissant Expedition 1906. Received from Prof. Cockerell.

Aphodius Illiger.

A. laminicola n. sp. Form stout, evidently a little more so than in the recent *A. fimetarius*, head narrowed anteriorly, clypeus almost squarely truncate at middle, the angles rounded. Prothorax broadest about the middle, sides apparently regularly arcuate but not alike in the specimen and therefore incapable of exact definition. The appearance is that the base was distinctly broader than the apex. Sculpture obliterated by the impressions of the underside, which show through. Scutellum (?) large, almost equilaterally triangular, the basal (anterior) angles obliquely truncate, basal region rugosely punctate, middle finely carinate. Elytra subparallel to an indeterminate distance behind the middle, regularly conjointly rounded at tip, striæ fine, single, finely and not closely punctured, interspaces broad and very nearly or quite flat with a few scattered fine punctures, sutural interval narrower than the next. Legs stout, middle tibia slightly bent at base, tip moderately expanded, median oblique ridge faintly indicated. Length 9·70^{mm}, of elytra 5·75^{mm}, of middle femur about 1·70^{mm}, of middle tibia 1·35^{mm}, of middle tarsus about 1·35^{mm}, conjoint width of elytra about middle 4·80^{mm}.

Station number 14. Collection number 231, Florissant Expedition 1906. Received from Prof. Cockerell. The type is in the Peabody Museum of Yale University (Cat. No. 13); a second, poorer specimen, a reverse, from the same station and with the catalogue number 140, is in the Museum of the University of Colorado.

The type specimen is very puzzling, on account of the peculiar state of preservation; the parts of the under side are largely shown through and interfere with the view of the upper surface. Thus I am not sure whether the structure described as the scutellum may not be the mesosternum, and on account of similar confusion I have not tried to give measurements for the head and prothorax. Of the legs, the two middle femora show plainly, the front and hind ones indistinctly. One middle tibia and the tarsus of the opposite leg are distinct.

Amphicoma Latr.

A. defuncta n. sp. The specimen shows only the tips of the elytra, with ill-defined exposed portions of the abdominal apex, some traces of hind wings, a well preserved hind tibia and tarsus and poorly indicated portions of the other leg of this pair. Elytra strongly dehiscent and tapering to the tip, which is rounded, surface clothed with hairs which are apparently longer and sparser than in the recent California *A. ursina.* The outer edge of each elytron shows a fine marginal bead, as in that species; the sutural bead is less strongly marked. No indication of discal sculpture, aside from the fine piligerous punctures, can be seen. The exposed tibia of the hind leg is perhaps a trifle stouter than in *A. ursina*, about equally broadened to the tip, the lateral margins (perhaps accidentally) irregular; one terminal spur shows, which is more than half as long as the first tarsal joint, but the extreme apex is concealed so that the exact length cannot be determined. Tarsi rather stout for this genus, the first joint longest (about one third longer than the one following) third and fourth joints nearly equal to each other and slightly longer than the second, claw joint again longer but ill defined, claws not in condition for study. Apparently, the first, second and third tarsal joints were finely longitudinally carinate above, a feature that I cannot detect in any recent *Amphicoma* at my disposal. Neither do I find any certain evidence that the legs were hairy, though I believe that certain sculpturings on the tibia represent piligerous punctures. The tarsal joints surely bore short stiff hairs on their margins, as in the recent *A. vulpina* from the New England coast. Width of elytral fragment, at 5^{mm} from tip, 3^{mm}; length of tibia, $4{\cdot}75^{mm}$; of tarsus, entire, $7{\cdot}25^{mm}$; of first joint about $1{\cdot}75^{mm}$.

Station number 14. Collection number 186, Florissant Expedition 1906. Received from Prof. Cockerell. The holotype is in the Peabody Museum of Yale University, Cat. No. 14.

Lema Fabr.

L. evanescens n. sp. Form similar to that of the recent *L. collaris* and equally stout. As the type is largely in profile, it is not possible to give comparative measurements of the length and breadth of different parts of the body, though the head, with greater portions of the eyes and antennæ, the prothorax, elytra, abdomen, and parts of the legs are more or less clearly shown. The antennæ are very nearly approximate at base and are stout, the intermediate joints but very little longer than broad; the eyes are large and prominent, legs stout. The specimen is a reverse, and lines of small elevations indicate that the elytra were punctured in rows similarly to most of our recent North American species. Total length, $5{\cdot}60^{mm}$; of elytron, $3{\cdot}60^{mm}$.

Station number not given. Collection number 86, Florissant Expedition 1906. Received from Prof. Cockerell. Type in Peabody Museum of Yale University, Cat. No. 15.

A second specimen, collected at Florissant in 1906 but with no station designated though bearing the collection number 107, is less in profile than the first and indicates that the prothoracic constriction was slightly antemedian and fairly deep. In this the broader elytron is $3{\cdot}65^{mm}$ in length and about $1{\cdot}30^{mm}$ in width.

Ologlyptus Lacordaire.

O. primus n. sp. The rather poorly preserved specimen indicates a species of moderate size and probably flattened form, approximating that of our recent *O. anastomosis.* The prothorax is broadest near the middle, sides regularly rounding, apex considerably narrower than the base but owing to incompleteness of the specimen the exact proportions cannot be given. Head obscured, antennæ with the median joints about as broad as long. Elytral sculpture apparently rough, but no details can be made out. Legs wanting. Length of specimen, which lacks a small portion of the tip of the elytra, 7·25^{mm}; of prothorax about 2·15^{mm}; width of elytra, conjoint, 3·65^{mm}; of prothorax (distorted?), 2·75^{mm}.

Station number 13. Collection number 154, Florissant Expedition 1906. Received from Prof. Cockerell. Holotype in the Peabody Museum of Yale University, Cat. No. 16.

The generic reference is not made with any great certainty, but the facies is decidedly that of several recent species of *Ologlyptus*, with which it has been directly compared. The prothorax appears to have the basal margin extending farther backwards than the points of the hind angles, much as in the Mexican *O. sinuaticollis* but to an even greater degree.

Macratria Newm.

M. gigantea n. sp. Form elongate, head small, short, prothorax very long and narrow, elytra conjointly much broader than the prothorax, sides subparallel, apices rounded, surface finely, distinctly and rather closely striate, the striæ finely, not closely punctured, interspaces flat. Middle leg not elongate and only moderately stout. Antennæ showing only a few intermediate joints which are sufficiently well preserved to indicate that they are longer than wide, but not greatly elongate. Length from front of head to tip of elytra, but exclusive of projecting abdominal organs, 8^{mm}. Length of head, as preserved, 1^{mm}; of prothorax, 2·10^{mm}; of elytra, 5·10^{mm}. Width of prothorax about 1·50^{mm}, of elytra, conjointly, 2·50^{mm}. The articulations of the leg joints are not well enough defined to permit of accurate measurements.

Station number 14. Collection number 9, Florissant Expedition 1906. Received from Prof. Cockerell. Holotype in the Peabody Museum of Yale University, Cat. No. 17.

The specimen has a decidedly Anthicide look, and in build as well as sculpture resembles our recent North American species of *Macratria* though far exceeding them in size. Possibly it may represent an extinct allied genus, but no characters are evident upon which to base a separation.

Iowa City, Iowa.

ART. V.—*A Feldspar from Linosa and the Existence of Soda Anorthite (Carnegieite)*; by HENRY S. WASHINGTON and FRED. EUGENE WRIGHT.

THE mineral described in this paper was found as loose crystals, together with crystals of kaersutite, at a small parasitic, cinder cone of the volcano Monte Rosso, on the island of Linosa, east of Tunis.* The chemical investigation was undertaken by the senior author and the optical by the junior.

Physical Characters.

The dark brown, pumiceous, basaltic lava clings so tenaciously to the crystal faces that it was not possible to obtain satisfactory material for crystallographic measurements. The crystals vary much in size, the largest one measuring 3·5^{cm} in length and about 2^{cm} in width. While some are fragmentary, others are wholly bounded by crystal faces. They are elongated parallel to the *a* axis, and are of simple crystal habit, being bounded by the forms (001), (010), (110), and (1$\bar{1}$0), on the assumption that the mineral is a triclinic feldspar.

Although the crystal faces do not lend themselves to goniometric measurement, the basal cleavage is highly perfect, and albite twinning lamellæ are occasionally well developed. On such a cleavage flake the angle between the basal cleavage planes of two adjacent albite lamellæ was measured on a two-circle goniometer with reducing attachment, and found to be 8° 3′. From this the angle $(001)\wedge(010) = 85° 59'$ can be deduced, this angle for albite being 86° 24′, for anorthite 85° 20′, and for labradorite 86° 12′. The cleavage after (010) is very imperfect, as is often the case with the soda-lime feldspars, and only indications of cleavage after the prism faces (110) and (1$\bar{1}$0) were noted. When the cleavage does not control, the fracture is highly conchoidal. Viewed along certain directions, especially about normal to the front pinacoid, a peculiar, milky, opalescent sheen, resembling that of moonstone, can be seen in some of the crystals.

Fine polysynthetic twinning lamellæ after the albite law are not uncommon, and occasionally cross polysynthetic twinning lamellæ, probably after the pericline law, were observed. On a plate nearly normal to the obtuse bisectrix the angle between the albite and the pericline twinning lamellæ was found to be 94°.

The specific gravity was determined (by H. S. W.) with the pycnometer on two separate portions of the carefully selected material used for the chemical analyses, and was found to be 2·692 at 3° and 2·693 at 17°. The latter may, therefore, be considered to be the specific gravity of the mineral, or, rather, correcting for about 0·75 weight per cent, or 0·35 volume per cent, of included magnetite, the true specific gravity of the mineral would be 2·684. The hardness is slightly less than that of adularia, but not far from 6.

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* Cf. H. S. Washington, Jour. Geol., vol. xvi, p. 10, 1908; and Washington and Wright, this Journal, vol. xxvi, p. 187, 1908.

Except for ferruginous stains derived from the inclosing basaltic scoria on the exterior portions of the crystals, and the very small and rare inclusions of magnetite to be described later, and which did not interfere with the optic determinations, the material is remarkably fresh, colorless and transparent, and admirably adapted for optic work. Zonal structure was not evident.

The refractive indices were measured in sodium light on an Abbé–Pulfrich total refractometer, the probable error of the values being less than ± ·001, with the following results:

$$\alpha_{Na}=1·5549,\ \beta_{Na}=1·5587,\ \gamma_{Na}=1·5634,$$
$$\gamma-\alpha=0·0085,\ \gamma-\beta=0·0047,\ \beta-\alpha=0·0038$$

According to these values the measured crystal plate was optically positive and $2V_{Na}=82°\ 48'$. On a second, less perfect plate slightly higher values were obtained, but the observed differences were only a little greater than the probable error.

The optic axial angle was measured directly on a Wülfing axial angle apparatus in sodium light, the plates being immersed in a liquid of the refractive index 1·559, the observed readings giving, therefore, at once the true optic axial angle $2V_{Na}$. Five plates normal to the bisectrix $\mathfrak{c}$ and one plate normal to $\mathfrak{a}$ were measured. The values thus obtained did not agree well, and several of the plates were remeasured with practically the same results.* The probable error of the values in the following table is certainly less than ±30′.

Crystal plate	$2V_{Na}$	Dispersion	Optical character	Extinction angle,† $a \wedge \mathfrak{a}$
1	78° 0′	$\rho>v$	+	28·0°
2	78° 29′	....	+	12·0°
3	84° 29′	$\rho>v$	+	6·2°
4‡	85° 41′	....	+	33·0°
5	89° 27′ §	....	—	11·9°
6	88° 59′ ‖	....	—	13·0°

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* We are indebted to Mr. E. S. Larsen, jr., of the Geophysical Laboratory, for an independent measurement of the optic axial angles of the entire set. His results are practically the same as those in the table, the greatest differences being 20′ on a less favorable plate.

† Too much stress cannot be placed on these extinction angles, since the plates were cut only approximately normal to the bisectrices and were out a number of degrees in certain instances.

‡ Plate cut normal to the obtuse bisectrix. 94° 18′ measured.

§ 90° 33′ measured.

‖ 91° 1′ measured.

These variations are of considerable magnitude and the values seem to differ from crystal to crystal rather than within a single crystal. This phenomenon of variation in optic axial angle might possibly be explained as a result of unequal cooling of the different crystals, as is the case with orthoclase and sanidine; but other evidence, particularly that of the extinction angles, shows that the composition probably varies slightly from crystal to crystal.

The extinction angles were measured both on cleavage flakes after (001) and on (010). In each case the angles were measured as accurately as possible, with the aid of the circularly polarizing bi-quartz wedge,* and the probable error is less than 15′.

On (001) the values for $a \wedge \mathfrak{a}$ ranged from −0·6° to −4·5°, and on basal cleavage flakes from one crystal the angles averaged −2·0°, and from a second −4·5°. Other pieces showing polysynthetic lamellæ were observed occasionally with very high extinction angles; but the examination in convergent light, and also the determination of the ellipsoidal axis, whether $\mathfrak{a}$ or $\mathfrak{c}$, proved that either the cleavage fragment was not parallel to the base or that pericline lamellæ were being examined.†

Extinction angles were also measured on the brachypinacoid (010), both on the rhomb-shaped cleavage flakes and also on a section ground parallel to the brachypinacoid. Different values were obtained for different flakes, although in the larger ground plates no marked indications of wavy extinction or zonal structure were observed. The values ranged from $a \wedge \mathfrak{a} = -2{\cdot}5°$ to −11°. Since, however, the cleavage parallel to (010) is not perfect, it is possible that part of this variation was due to the fact that the surfaces were not precisely parallel to (010) at the place of measurement, but were inclined because of minute irregularities of the cleavage. Flakes parallel to (010) often show in white light the peculiar interference phenomena characteristic of minerals with slight dispersion of the bisectrices.

In convergent polarized light the optic normal emerges near the center of the field on plates parallel to (001); while the bisectrix $\mathfrak{c}$ is nearly normal to the brachypinaoid, and appears near the center of the field on flakes parallel to (010).

Taken collectively, these results indicate that the present material is a plagioclase feldspar, of somewhat variable composition and with slightly modified characters. Taken alone, the extinction angles on (001) would indicate a feldspar composition ranging from about $Ab_{11}An_6$ to $Ab_{21}An_{20}$, while from those on (010) a composition from $Ab_{11}An_5$ to $Ab_{13}An_{10}$ and higher might be inferred. The values of the optic axial angle alone indicate variations from $Ab_{27}An_{20}$ to Ab_6An_5, according to the most accurate measurements of the different members of the plagioclase series. As a whole, therefore, the optic characters would show that we have an andesine feldspar of a composition somewhat more sodic than Ab_1An_1, on an average about Ab_3An_2, while the specific gravity is almost exactly that of a labradorite of the composition Ab_1An_1, or (corrected) of an andesine Ab_8An_4.

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*Cf. F. E. Wright, this Journal, vol. xxvi, p 391, 1908.

† A series of measurements on 12 different cleavage flakes from one of the crystals was also made by Mr. E. S. Larsen, with the result $a \wedge \mathfrak{a} = 2° 2' \pm 6'$, a value well in accord with Wright's observations.

Chemical Composition.

The material used for the chemical analyses was obtained by coarsely crushing several of the crystals and fragments and very careful hand-picking under the lens. It was found to be impossible to separate the portions contaminated with adherent basaltic scoria by means of heavy solutions. Because of the similar specific gravities, particles with and without attached scoria floated and sank together. In the heavy solution the material used for analysis seemed to be homogeneous.

All the material analyzed was perfectly fresh, colorless, and water-clear, and consisted of but one mineral, so far as could be ascertained by examination under the microscope. While the greater portion was entirely free from inclusions, it was impracticable not to use some fragments containing inclusions, and as these have a bearing on the chemical discussion, they may be briefly described here. Apart from them the material was perfectly pure and admirably suitable for chemical analysis.

The inclusions are never very abundant, especially in the fragments used for the analyses. They are very minute in size, the largest being $0{\cdot}5^{mm}$ long by $0{\cdot}1^{mm}$ wide, and the great majority are much smaller. They are of uniform character, in the form of narrow, spindle-shaped bodies or thin cylinders with rounded ends. They are black, with metallic luster, and perfectly opaque, so that they may be regarded as essentially magnetite, a conclusion also indicated by the results of the analyses.

The feldspathic mineral is only slightly acted on by hot, dilute hydrochloric acid, even after prolonged treatment, so that the main portion was brought into solution by fusion with mixed sodium and potassium carbonates. In this, as in other respects, the analyses were made by the methods advocated by Hillebrand and by Washington, the alkalies being determined by the Smith method.

An analysis was made in duplicate (except for FeO, the alkalies and H_2O) on one lot of selected fragments, portions of which also served for the specific gravity determinations, the material being dried at 110°. As the results were decidedly unexpected, especially in view of the preliminary optic work, a second lot of fragments was analyzed, special care being taken to select, so far as possible, only those showing cleavage surfaces, so as to exclude any possible nephelite. The results of the three analyses, with the average and the molecular ratios of this last, are given below.

	I	II	III	Average	
SiO_2	52·73	52·75	52·83	52·77	·874
TiO_2*	trace	trace	trace	trace	
Al_2O_3	29·34	29·54	29·63	29·50	·290
Fe_2O_3	0·67	0·75	0·53	0·65	·004
FeO	0·17	(0·17)	(0·17)	0·17	·002
MgO	0·03	0·05	0·07	0·05	·001
CaO	10·73	10·59	10·67	10·66	·190
Na_2O	5·40	(5·40)	(5·40)	5·40	·087
K_2O	0·74	(0·74)	(0·74)	0·74	·008
H_2O	0·38	(0·38)	0·34	0·36	
	100·19	100·37	100·38	100·30	

The very small amounts of iron oxides and magnesia are evidently derived from the small, opaque inclusions. Ferric oxide is in excess of ferrous, but in the determination of such small amounts the fact is not of much significance, so that the figures bear out the microscopic examination in the conclusion that the inclusions are of a (non-titaniferous) magnetite. They also probably contain the magnesia. We may, therefore, safely reject the small amounts of ferric and ferrous oxides, magnesia and water, which last is to be ascribed to adsorption of atmospheric moisture† by the powder. On this basis the composition deduced from the analysis will be as follows:

	Linosa mineral			$(\frac{1}{3}Na_2\frac{2}{3}Ca)Al_2Si_3O_{10}$	Ab_1An_1	Ab_3An_2
SiO_2	53·26	·882	9·09	52·84	55·67	58·24
Al_2O_3	29·78	·291	3·00	29·94	28·26	26·53
CaO	10·76	·192	1·98	10·96	10·34	8·32
Na_2O	5·45	·088	0·99	6·26	5·73	6·91
K_2O	0·75	·008		0·00	0·00	0·00
	100·00			100·00	100·00	100·00

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* The color produced by H_2O_2 in the solution used for the titration of iron as Fe_2O_3 was barely perceptible, so that only faint traces of titanium can be present.

† Cf. Day and Allen, Carnegie Publication, No. 31, 1905, p. 57.

The ratios of the Linosa mineral are very close to whole numbers, though there is a slight excess of silica. Calculating the small amount of potash with the soda, the figures of the analysis correspond to the formula $Na_2O.2CaO.3Al_2O_3.9SiO_2$, which, simplified, becomes $(\frac{1}{3}Na_2, \frac{2}{3}Ca)Al_2Si_3O_{10}$. The percentage composition of this molecule is given above.

No anhydrous silicates with formulas corresponding to this appear to be known independently, but several zeolites are analogous, namely: wellsite, $(K_2, Ca, Ba)Al_2Si_3O_{10}+3H_2O$; edingtonite, $BaAl_2Si_3O_{10}+3H_2O$; natrolite, $Na_2Al_2Si_3O_{10}+2H_2O$; and a potassium natrolite observed by Pirsson* in missourite with the approximate composition $(K_2Ca)Al_2Si_3O_{10}+2H_2O$. Indeed, the composition of the Linosa mineral is exactly that of a mesolite, $(mNa_2Al_2Si_3O_{10}.2H_2O+nCaAl_2Si_3O_{10}.3H_2O)$, with $Na_2O : CaO = 1 : 2$, and lacking the water.

Compounds of this type can be regarded as salts of the alumo-trisilicic acid $(H_2Al_2Si_3O_{10})$ of Morozewicz,† the potassium salt of which he considers as present in nephelite, with varying proportions of the sodium alumo-disilicate, $(Na_2Al_2Si_2O_8)$. Reduced to still simpler terms they would be salts of the acid $H_8Si_3O_{10}$, for which Vogt‡ proposes the name pyrosilicic acid. He refers akermanite and gehlenite to this simple formula, as does Tschermak § the mineral melilite.

Comparing the composition of our mineral with those of the two plagioclases, Ab_1An_1 and Ab_3An_2, which it closely resembles in its physical properties, it will be seen from the table above that Ab_1An_1 shows closely concordant figures for lime and soda, while silica is distinctly higher and alumina lower; and that, on the other hand, Ab_3An_2 shows much higher silica and slightly higher soda, but lower lime and alumina. In fact a composition satisfactorily close to that of the Linosa mineral as regards all the constituents, and furnishing like ratios, cannot be calculated from mixtures of the albite and anorthite molecules.

The relations may be better seen in the respective ratios, as shown when the formulas are compared, as follows:

Linosa mineral $= Na_2O.2CaO.3Al_2O_3.9SiO_2$.
Labradorite $(Ab_1An_1) = Na_2O.2CaO.3Al_2O_3.10SiO_2$.
Andesine $(Ab_3An_2) = 3Na_2O.4CaO.7Al_2O_3.22SiO_2$.

Discussion.

The data given in the preceding pages make it clear that the physical and chemical characters of our mineral are at variance. The crystal system, twinning laws, cleavage, and hardness are those of the lime-soda feldspars. The specific gravity, the crystallographic angles measured and the birefringences are those of a labradorite of about the composition Ab_1An_1. Although the optic axial angle and the extinctions are decidedly variable, they correspond to those of andesines somewhat more sodic than Ab_1An_1, on the average about Ab_3An_2. On the other hand, the chemical composition is not that of any possible member of the normal plagioclase series, or mixtures of albite and anorthite. The ratios of Al_2O_3, CaO and Na_2O are those of Ab_1An_1, but the amount of SiO_2 is lower than that demanded for these by the known feldspar formulas, and the mutual ratios of this with those of the other constituents indicate a composition which corresponds to that of an anhydrous mesolite, or a salt of the acid $H_2Al_2Si_3O_{10}$, with $Na : Ca = 1 : 1$. Our mineral is, therefore, physically closely allied to labradorite and andesine, but chemical distinctly different in the ratios of the constituents.

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* Weed and Pirsson, this Journal, ii, p. 320, 1896.

† Morozewicz, Bull. Acad. Sci. Cracov., p. 999, 1907.

‡ Vogt, Mineralbildung in Schmelzmassen, p. 162, 1892.

§ Tschermak, Lehrbuch der Mineralogie, p. 523, 1905.

The possibility that the material analyzed was a mechanical mixture of particles of two minerals, such as labradorite and nephelite, and that only fragments of the former were subjected to optic investigation, is rendered untenable by the following facts. Careful examination of the unbroken crystals, as well as microscopic study of the crushed fragments and cleavage flakes, by both of the authors independently, revealed the presence of but one mineral, colorless, transparent, cleavable and feldspar-like. Apart from the small, opaque inclusions, each crystal appeared to be homogeneous, and all appeared to be of identical material, except for the optic variations. The action of hydrochloric acid showed that no readily decomposable mineral was present as separate individuals. The very close agreement between separate portions in specific gravity and in chemical composition renders the mathematical chances against the hypothesis of a mechanical mixture of particles of two minerals so great that it may be safely eliminated from consideration. Finally, the lavas of Linosa are all typical feldspar basalts, and only a few very small amounts of nephelite possibly existent as a glassy base. Assuming, therefore, that the material was homogeneous, two hypotheses present themselves to account for the anomalies observed.

One is that the Linosa mineral is to be regarded as a distinct species, chemically, of the formula $Na_2Ca_2Al_6Si_9O_{30}$, but with physical properties which correspond very closely to those of a plagioclase of the composition Ab_1An_1 to Ab_3An_2. The uniformity of the material as shown by the specific gravity and the chemical analyses and, above all, the very close approach to exact rationality of all the ratios, are in favor of this view. But the peculiarities of chemical composition are explicable in another way, and as it would be contrary to our notions of the definitions of mineral species to consider two chemically similar minerals as distinct which possess essentially identical crystallographic form and physical and optic properties in so many respects, we may also disregard this hypothesis.

The alternative view is that the mineral is a labradorite of abnormal optic characters and chemical composition, due to the presence of another mineral in intimate molecular mixture as a mixed crystal or solid solution. The amount of this must be small, and in its optic characters the subordinate mineral should presumably resemble a plagioclase, since the optic constants of the Linosa mineral are essentially those of a lime-soda feldspar, but indicate a composition somewhat more sodic than that indicated by the specific gravity.

The range of possibilities as to the mineral molecule which may be supposed to be admixed molecularly with the labradorite is very limited, as it must be, chemically, an alumino-silicate of either soda or lime, or of both of these, with alumina equal molecularly to the basic oxide or oxides, and with the ratio of silica to bases less than in labradorite. Furthermore, it seems necessary to assume that the base is soda alone, because if the subordinate mineral is purely calcic, all the soda entering albite, the lime must be equally distributed between the molecules $CaO.Al_2O_3.2SiO_2$ (anorthite) and $CaO.Al_2O_3.SiO_2$, to obtain the ratios and percentages shown by our mineral. This calcic subsilicate is not known to occur either in nature or artificially, its nearest analogue being kornerupine, $MgO.Al_2O_3.SiO_2$, and its existence does not seem probable. Also no mineral in which $CaO+Na_2O = Al_2O_3$ is known which suits the requirements of the case.

The sodium-aluminum metasilicate, $Na_2O.Al_2O_3.4SiO_2$, occurs in nature as jadeite, and might also presumably exist as an isometric and isotropic soda-leucite. The presence of this molecule would yield a composition identical with that of our mineral, if soda is equally distributed between this and albite, the whole forming the mixture: $Na_2O.Al_2O_3.6SiO_2+Na_2O.Al_2O_3.4SiO_2+4(CaO.Al_2O_3.2SiO_2)$. But the presence of either of these mineral molecules may be considered as impossible here, on crystallographic as well as on optic grounds.

The most probable mineral molecule, therefore, is the orthosilicate $Na_2O.Al_2O_3.2SiO_2$. Assuming this to be present, the composition of the Linosa mineral in terms of mineral molecules can be calculated to be as follows:

$KAlSi_3O_8$	·016	·154	7·84	4·48
$NaAlSi_3O_8$	·137			36·16
$CaAl_2Si_2O_8$		·192	9·84	53·78
$Na_2Al_2Si_2O_8$		·019	1·00	5·58

Reckoning the small amount of potash as orthoclase with the albite molecule, the ratios of albite, anorthite and sodium alumino-metasilicate approximate closely to whole numbers, and are almost exactly 8 : 10 : 1. The labradorite would thus have the composition Ab_4An_5, while we have seen that the optic data indicate that the mineral is actually somewhat more sodic, from about Ab_1An_1 to Ab_3An_2.

The molecule $Na_2Al_2Si_2O_8$ is that of potash-free nephelite, which does not seem to occur in nature, but which has been made artificially in small hexagonal crystals, much like those of nephelite, and with a specific gravity of 2·555.[*] If this mineral were present it would necessarily be as a mechanical mixture or as what has been termed[†] an "anomalous solid solution," since it is not crystallographically isomorphous with the triclinic albite and anorthite, and true solid solution or a mixed crystal, containing such an amount of the subordinate mineral as shown above, would hardly be expected in such dissimilar minerals.

True solid solution could take place, however, if the molecule $Na_2Al_2Si_2O_8$ is dimorphous, and a second form exists whose symmetry relations approximate those of anorthite and albite. The two formulas

$$\begin{array}{ll} \text{Anorthite,} & CaO.Al_2O_3\ 2SiO_2 \\ \text{Nephelite,} & Na_2O.Al_2O_3.2SiO_2 \end{array}$$

are identical, except that in the second Na_2O replaces the CaO of the first, and it is not out of the range of possibility that a soda anorthite should exist. This mineral is not yet known to occur in nature, but its presumable characters would harmonize the conflicting data. Thus, it should be triclinic and isomorphous with albite and anorthite, and therefore capable of forming mixed crystals with these analogous to the ordinary plagioclase series. Similarly, it would presumably possess optic characters more sodic, that is, more like those of a soda-lime feldspar, than those of purely calcic anorthite; so that we would thus have an explanation of the fact that, while the relations of CaO and Na_2O in our mineral are those of Ab_1An_1, certain of the optic characters are those of a more sodic plagioclase. Since the specific gravity of nephelite, and presumably also of the soda anorthite, is less than that of anorthite, the density of the mixed crystal should be less than that of the equivalent plagioclase in which no soda anorthite occurs, and we have seen that, while the normal plagioclase present is about Ab_4An_5, which would have a density of 2·698, the density of our mineral is that of Ab_1An_1 or Ab_5An_4.

[*] Cf. Hintze, Mineralogie, vol. ii, p. 97.

[†] A. Johnsen, Neues Jahrbuch, 1903, ii, p. 93.

From the above data on the percentage composition in terms of the different mineral molecules (Or, Ab, An, Ne), the specific gravity of the mineral can be calculated on the assumption that no great volume change in the component molecules has taken place, a condition which experience has shown to hold true for practically all cases of solid solution. The weight per cent of each molecule present, divided by its density in crystallized condition, furnishes its specific volume or its volume compared with water of equal weight. The sum of these specific volume values for all the molecules present denotes in turn the specific volume of the substance, the reciprocal of which is the density required. In this calculation the most accurate density determinations of the components were used, namely: Or = 2·55, Ab = 2·605, An = 2·765, and Ne = 2·571 (the last determined on artificial triclinic Na_2Al_2-Si_2O_8). The resulting density, 2·685, approximates very closely the measured density, 2·693, and is almost identical with this as corrected for the magnetite inclusions, 2·684. This in itself is a strong proof that the Linosa mineral is a mixed crystal of feldspar and soda anorthite.

This complex mineral would belong logically to the group of feldspars, just as do the barium-bearing members of the orthoclase-celsian series, some intermediate members of which are called hyalophane, and which contain the molecule $BaAl_2Si_2O_8$. In this connection it is interesting to note that a sodium-barium plagioclase, described by Des Cloiseaux,* was crystallographically similar to albite-oligoclase, optically like a labradorite, and with the oxygen ratios of andesine. Mentioning this mineral, Rosenbusch† points out that, as celsian is monoclinic, the barium alumino-silicate must be dimorphous.

The Linosa mineral would thus be a representative of a distinct and hitherto unrecognized triclinic feldspar series, characterized by the joint presence of molecules of albite, lime anorthite, and soda anorthite. Reckoning in with the soda the small amount of potash present, and distinguishing the lime and soda anorthites as Can and Nan respectively, our feldspar would have the composition $Ab_8Can_{10}Nan_1$.

Regarded as a feldspar of such abnormal character, and especially if the assumption is verified that soda anorthite is present and that we are dealing with a representative of a new feldspar series, the Linosa mineral is deserving of a new name. For this we propose *anemousite*, after the ancient Greek name of the island. The term anemousite would imply, of course, not only a feldspar with the exact composition given above, but, like hyalophane, oligoclase, labradorite, etc., could be

* Tscherm. Min. Mitth., p. 99, 1877.

† Mikr. Phys., vol. i, part ii, p. 313, 1905.

applied to feldspars composed of the three molecules mentioned in somewhat varying ratios. If more representatives of the series are discovered, these limits might be more sharply defined, centering round the composition of the present case.

The very close approach to stoichiometric ratios of the oxides may seem to be inconsistent with the view that the mineral is an isomorphous mixture or solid solution. It is, however, in harmony with the well known fact that solid solutions tend to form with their elements in simple ratios, in which case they possess greater stability, giving rise to the substances known as molecular compounds. This is exemplified in many mineral groups, such as the plagioclases, pyroxenes, olivines, nephelite, and the calcite group, the intermediate members of which are very apt to show simple ratios of the end components.

The fact that soda anorthite is not known to occur independently in nature cannot be brought up against the hypothesis of its presence in this case, as the assumption of the presence of a molecule unrepresented by itself in nature is not uncommon in explaining the constitution of many complex mineral groups. Its non-existence as a mineral may be best explained on the ground that the conditions necessary to its formation seldom obtain, the physical conditions being generally such that the more stable nephelite is formed in its stead.

Assuming the presence of the soda-anorthite molecule, it is certainly remarkable that it does not appear to have been detected as yet among the hundreds of chemical analyses which have been made of the feldspars. It would seem to be certain, at least, that it does not enter into the composition of many of these, so far as known, and that, if present at all, it forms only a very small percentage of the feldspar substance, so that its effect in altering the silica ratios would either be overlooked or attributed to impurities or analytical error.

It is a plausible, and indeed reasonable, supposition that we have to do here with a case of imperfect isodimorphism or limited miscibility, as it is termed,* instances of which have been investigated by Retgers and others. As stated by Groth: "If the temperature intervals for the stability of the individual modifications of two substances differ so widely that, under the conditions ruling during the crystallization, the corresponding state of the one substance is metastable, then as a rule this substance can crystallize along with the other in the form which is stable for it [the other], but only to a limited extent." This is illustrated by monoclinic $FeSO_4.7H_2O$ and orthorhombic $MgSO_4.7H_2O$. Monoclinic mixed crystals with the form of the former can be obtained with up to 54 per cent of magnesium sulphate, indicating the existence of a monoclinic form of this salt. Then a gap occurs, until we obtain orthorhombic mixed crystals with 81 to 100 per cent of the magnesium salt, showing the existence of an orthorhombic ferrous sulphate. Very unstable monoclinic crystals of the magnesium salt have been prepared, but orthorhombic ferrous sulphate is as yet unknown in the free state. An analogous case is that of rhombohedral sodium nitrate and orthorhombic silver nitrate. Rhombohedral mixed crystals have been prepared containing up to 52·5 per cent of silver nitrate, while orthorhombic crystals containing only up to 4·5 per cent of sodium nitrate have been obtained. In accordance with these results, no orthorhombic modification of sodium nitrate is known, but the pure rhombohedral silver salt is formed from fusion on cooling.

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* Cf. P. Groth, Introduction to Chemical Crystallography, New York, 1906, p. 92.

Analogously we can suppose that $Na_2Al_2Si_2O_8$ and $CaAl_2Si_2O_8$ are isodimorphous, each forming hexagonal and triclinic modifications. Of these, however, only the hexagonal form of the sodium salt and the triclinic form of the calcium salt are stable under ordinary pyrogenetic conditions, while the converse forms are metastable and capable of existence in mixed crystals with the other only in small amount and within a very narrow range of temperature or other physical conditions. The calcium almost always present in nephelite, up to about two per cent, may be thus regarded as existent as hexagonal calcium nephelite,* which must possess a very limited degree of stability, while the stability of the triclinic modification of the sodium salt is apparently somewhat greater, to judge from the percentage shown by anemousite.

It is obvious that the existence of soda anorthite and its presence in the lime-soda feldspars, or the possibility of the assumption by these of other molecules in solid solution, would have a very important influence on determinative mineralogy and petrography. The optic characters of such an abnormal feldspar would not indicate its true chemical composition in accordance with the tables and diagrams in use at present, as the feldspar would be apparently more sodic than it is in reality. The optic determination of the soda-lime feldspars in thin section would thus not be the comparatively simple and unerring matter that it is now supposed to be, as the possibility of the presence of soda anorthite and its influence on the optic constants would have to be taken into consideration. The recognition of celsian introduces a similar uncertainty.

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* Morozewicz (op. cit., p. 988) and others consider the calcium as replacing the sodium in nephelite.

Again, assuming the possibility of existence of soda anorthite, it would presumably depend on the conditions controlling during crystallization, whether the sodium-alumino orthosilicate would crystallize as nephelite in separate individuals, or as soda anorthite in mixed crystals with albite and anorthite. With identical chemical composition of the rock, we would have in the one case a nephelite tephrite, and in the other a feldspar basalt, but the norms of both would be the same and would show normative nephelite, since nephelite and soda anorthite are normatively the same molecule. We might explain in this way the anomaly of certain holocrystalline rocks containing plagioclase, the norms of which show considerable nephelite, though none of this mineral is present in the mode; and this may be applied to the normatively nephelitic feldspar basalts of Linosa itself. In some cases, of course, the discrepancy is to be attributed to the readjustments of the normative molecules due to the formation of other modal minerals. and the case is mentioned as illustrating some of the petrographic possibilities consequent on the existence of soda anorthite.

The points brought out in the preceding paragraphs indicate the importance and necessity of the verification of the assumed existence of soda anorthite, before any modification is called for of our ideas in regard to the composition and constitution of the soda-lime feldspars, based as these are on the large amount of accurate work by Tschermak, Schuster, Fouqué, Michel Lévy, Fedorow, and others. The very general agreement of the observations of all these workers with the theory that only mixtures of $NaAlSi_3O_8$ (albite) and $CaAl_2Si_2O_8$ (anorthite) are involved is strong evidence in favor of its general truth, and points to the conclusion that, if present at all, the amount of soda anorthite must be very small in most feldspars so far examined. On the other hand, the occasional very notable divergences from the figures demanded by the premises and the variability of the feldspars optically, indicate the possibility of the presence of some modifying constituents one of which might well be the molecule suggested by us.

The Formation of Soda Anorthite.

Fouqué and Michel Lévy* succeeded in 1880 in producing oligoclase, labradorite, and anorthite containing strontium, barium and lead, instead of calcium, but they did not apparently attempt the formation of soda anorthite.

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* Synthèse des Minéraux et des Roches, Paris, 1883, p. 145.

The possibility of the existence of this mineral seems to have been first pointed out by Lemberg,[*] though he did not succeed in preparing it, and he remarks on its probable instability under ordinary conditions.

Soda anorthite seems to have been actually formed by S. J. Thugutt[†] by heating artificial "nephelite hydrate" to a white heat, followed by rapid cooling. A crystalline melt was obtained which contained lath-shaped sections of an apparently triclinic mineral, which showed numerous polysynthetic twinning lamellæ, with extinction angles of about 36°. The photomicrographs in Thugutt's paper show clearly sections of this twinned plagioclase-like substance.

E. Esch[‡] describes a nephelite in the nephelinite from the Etinde volcano in German Kamerun. This nephelite shows extraordinary optic properties, and in all probability is triclinic, the crystals being intricately twinned so as to resemble an apparently simple nephelite crystal. The individuals are biaxial, with small optic axial angle, optically negative, and so twinned that basal sections are often divided into sextants, one of which may be normal to a negative acute bisectrix, while the opposite sextant is then about normal to the positive obtuse bisectrix. From this behavior, combined with large extinction angles, Esch considers the mineral to be triclinic.

It may also be noted, as germane to the present subject, that the corresponding potassium alumino-silicate, $K_2Al_2Si_2O_8$, has been produced artificially in several modifications which differ crystallographically from the natural mineral kaliophilite.[§] One of these, formed by Lemberg and examined by Lagorio, was in aragonite-like twins, resembling those of the Etinde nephelite. Another was isometric, while those formed by Weyberg were prismatic and possibly tetragonal.

In the Geophysical Laboratory, soda anorthite was first obtained in 1905 by Dr. Allen by fusing together the component oxides in proper proportions. The resulting glass was clear and brilliant[‖] but contained bubbles here and there, and although it softened gradually at high temperatures it was not as viscous as albite glass. The power of crystallization of this substance from the pure melt is not so great as that of many silicates, owing to its high viscosity. The glass was crystallized by heating it to 1080°, and was examined by

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[*] Zeitschr. deutsch. geol. Ges., vol. xl, p. 641, 1888.

[†] Neues Jahrb., Beil. Bd. ix, p. 561, 1894.

[‡] Sitzb. Berl. Akad., vol. xviii, p. 400, 1891.

[§] Cf. Z. Weyberg, Centralblatt Min. etc., p. 395, 1908.

[‖] For a determination of the refractive indices of this glass, the writers are indebted to Mr. E. S. Larsen, of the Geophysical Laboratory. His values were obtained by the minimum deviation method with a polished prism of the glass. The results were: $n_{Na} = 1·5181$, $n_{Li} = 1·5148$, $n_{Tl} = 1·5208$.

Wright at the time. It varied in granularity and, except for occasional patches of more crystalline material, was too fine for optic determinative work. No separate crystals were obtained and no goniometric measurements could therefore be made. Since 1905 repeated experiments have been made with the crystallization of this substance from the melt, and also by heating the glass at different temperatures, but the results of the optic examinations have been practically the same in each case, and the different experiments need not be considered in detail here.

FIG. 1.

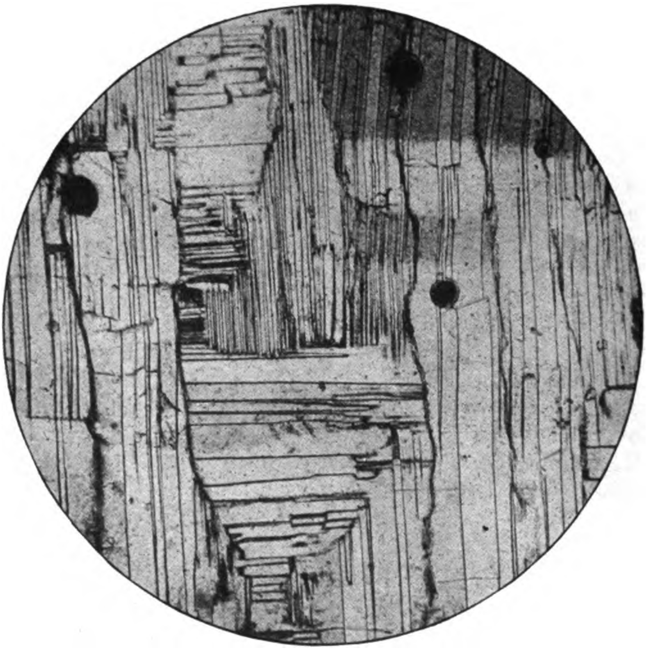

FIG. 1. Polysynthetic albite-like twinning on artificial soda anorthite. Nicols crossed. Magnification 85 diameters.

The most characteristic feature of this form of $Na_2Al_2Si_2O_8$ is its polysynthetic twinning, which in many instances closely resembles that of the plagioclases (fig. 1). On other sections the cross grating twinning of microcline is developed, and if encountered in a rock section might easily be mistaken for this (figs. 2 and 3). The extinction angles on such polysynthetically twinned individuals ranged up to 44° on symmetrically extinguishing sections, the angles between the (c) ellipsoidal axes of adjacent lamellæ being 88°. As in the plagioclase lamellæ, the extinction angles in the zone of symmetry varied with the position of the sections, and the symmetrical extinction angles most commonly observed ranged between 35° and 40°, the ellipsoidal axis c being next the twinning junction line in each case.

In many of the sections showing apparently albite twinning lamellæ, a second set of polysynthetic lamellæ often appeared, making usually angles of 57° to 63° with the first, and so distributed in the lamellæ of the first set as to be symmetrical to its planes of twinning. Thus, if the lamellæ of the first set (albite lamellæ) are placed in a north-south direction, then in lamella No. 1 of this set the lamellæ of the second set trend N. 60° E. approximately, while in the adjacent lamellæ No. 2 of the first set the lamellæ of the second set trend N. 60° W., the N.-S. direction acting as a plane of symmetry. The positions of extinction of the interposed lamellæ in any given twinning band of the first set agree closely with the extinction positions of the immediately adjoining second lamellæ of the first set.

FIG. 2.

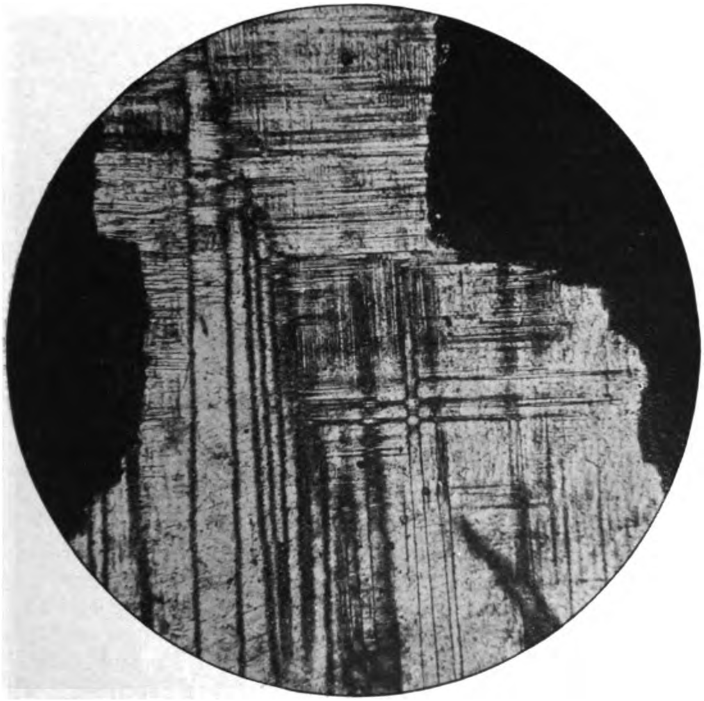

FIG. 2. Polysynthetic microcline-like twinning on soda anorthite. Nicols crossed. Mag. 75 diameters.

The general tendency of this involved twinning is to produce a hexagonal network of interpenetrating lamellæ, but ordinarily one set predominates and the other sets appear only dimly outlined in the background.

As a result of this complicated twinning, single individual grains suitable for optical work were rarely observed, and were then too small for accurate measurements. Optic axial angle determinations were influenced particularly by this condition, and although much time was spent in searching for suitable sections, the angular values obtained varied considerably. The most probable value for 2V is about 36°±5°. The optic character is negative. The refractive indices were determined by the immersion method : $\alpha = 1·516 \pm ·003$, $\gamma = 1·520 \pm ·003$. The birefringence is weak and was measured on several sections, the highest value for α-γ being 0·0042.

Fig. 3.

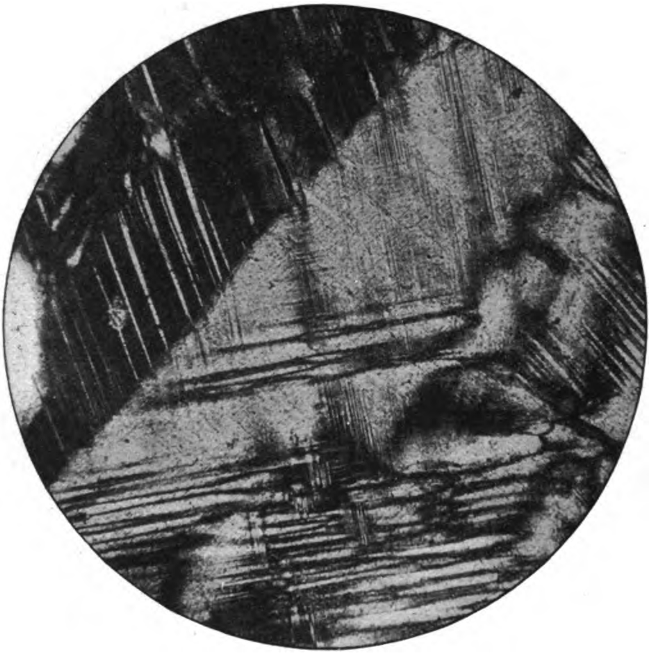

Fig. 3. Polysynthetic twinning on artificial soda anorthite. Nicols crossed. Magnification 75 diameters.

The specific gravity of soda anorthite was determined by the pycnometer method of Day and Allen, and the value 2·571 at 25° was obtained.

Experiments on the melting temperature of soda anorthite have been made, and also on the relation between soda anorthite and nephelite, whether they are monotropic or enantiotropic, but the results are not yet decisive, and mention of them will be deferred until more definite information is at hand.

In one of the preparations crystallized at about 1100°, single grains free from twinning were observed, which proved to be uniaxial and optically negative, and similar to nephelite in other properties, except that the refractive indices were very slightly lower. Artificial nephelite has been produced by several workers.*

The effect of an impurity, or of the presence of other substances, on the stability of soda anorthite has not yet been determined. It is, however, of interest to note that, while soda anorthite crystallizes invariably out of the pure $Na_2Al_2Si_2O_8$ melt, crystals obtained by melting down natural nephelite from Magnet Cove, Arkansas, and then allowing it to crystallize, were uniaxial and optically negative, and agreed in optic properties with the original nephelite. Natural nephelite is not the pure sodium salt, contains but notable but varying amounts of potassium as ever-present and essential constituent, and from its melt not a trace of the triclinic form was observed to crystallize out.

It is to be hoped that eventually well-developed crystals of soda anorthite will be obtained suitable for precise optic and goniometric work, because then its relation to the plagioclase feldspars, whether isomorphous or not, can be positively determined. The fact of its notable solid solution in the Linosa plagioclase, the similarity in twinning phenomena, refractive indices, birefringence, specific gravity, triclinic symmetry relations, and also in the chemical formulas, are strong arguments in favor of close crystallographic resemblance and probable isomorphous relations between soda anorthite and the plagioclase feldspars.

In the preceding pages the name soda anorthite has been applied to the triclinic phase of $Na_2Al_2Si_2O_8$, this having been used previously by Lemberg and Thugutt. While this name has some justification by analogy, and might serve as a provisional designation, yet it is open to serious objections. In the first place it is not in harmony with the usual nomenclature of the feldspars, soda orthoclase, for instance, signifying not a purely sodic monoclinic feldspar, but an orthoclase in which sodium partially replaces potassium. Also if, as is probable, the presence of this $Na_2Al_2Si_2O_8$ molecule is verified in other feldspars, the use of the term soda anorthite will be apt to lead to awkwardness and ambiguity. The compound name, furthermore, does not lend itself to the formation of an appropriate symbol, as Ab, An, and Or, for use in feldspar formulas; and finally the new triclinic feldspar, which has been actually formed in a pure state, and which we have shown to be capable of existence in nature in mixed crystals, is of such practical and theoretical importance as to deserve a special and distinctive designation. For these reasons we propose to substitute for the earlier and essentially descriptive term soda anorthite, applied to the triclinic form of $Na_2Al_2Si_2O_8$, the name *Carnegieite* (symbol Cg), in honor of the founder of the Institution under whose auspices the mineral was collected and the present investigations were undertaken.

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* Fouqué and Michél Levy, C. R., lxxxvii, p. 961, 1878; xc, p. 698, 1880; and Bull. Soc. Min. Fr., ii, p. 116, 1879; and iii, p. 118, 1880; Hautefeuille, Ann. de l'École Moun. Supér., ix, 1880: Bourgeois, Ann. Phys. Chim., 1883, p. 19: Doelter, Zeitschr. Kryst., ix, p. 321, 1884; C. and G. Friedel, Bull. Soc. Min. Fr., xiii, p. 129, 1890.

Locust, New Jersey, and
Geophysical Laboratory of the
Carnegie Institution of Washington, D. C., October, 1909.

ART. VI.—*Some Rare and Imperfectly Known Brachiopods from the Mississippian*; by DARLING K. GREGER.

THE four species of Brachiopoda which are figured here have caused not a little confusion to collectors of Mississippian fossils, the writer having frequently observed them severally labeled as the *Rhynchonella ringens* of Swallow, in local collections. That the shell described by Prof. Swallow under the name above referred to may be definitely known, and that a distinctive appellation may be had for the forms long confused with it, is the object of the present paper.

Camarophoria ringens (Swallow). Figs. 7, 8.

Rhynchonella ringens Swallow, 1860, Trans. Acad. Sci. St. L., Vol. II, page 653.

Original description.—"Shell large, thick, triangular, plicated, truncated and flattened in front. Ventral valve flattened, triangular; the anterior and the posterior lateral margins abruptly turned up to meet the dorsal valve; the anterior lateral margins curved down in the opposite direction; beak acuminate; sinus wide and shallow, containing about eight plications. Dorsal valve more convex; anterior and posterior lateral margins abruptly turned down to meet the opposite valve; strongly arched towards the anterior lateral margins. The juncture of the valves is sharply and deeply serrated. Surface marked with about fourteen large plications on each valve. Length, 1·90; breadth, 1·48; thickness, 0·99."

The plications all have their origin at or near the beak and increase in size as they approach the front, the number occupying the sinus and fold being quite variable; their number is never increased either by implantation or bifurcation over the body of the shell.

The specimen we figure is from the Boyce collection and bears a label written by the late Prof. Swallow; and while it is not so large as the type, we have no reason to doubt its being the species to which his description applies, since we have collected from the Burlington cherts of Callaway county numerous single valves that equal the dimensions given by the author. Locality and horizon of the figured specimen, and a number of others in our collection—East of New Bloomfield, Callaway county, Mo., in residual cherts of the Burlington limestone.

That the shell figured by Dr. Girty* from the Madison limestone is not conspecific with *Camarophoria ringens* is obvious if one follows the description with care, but whether Dr. Girty's shell should be referred to our *Paraphorhynchus*

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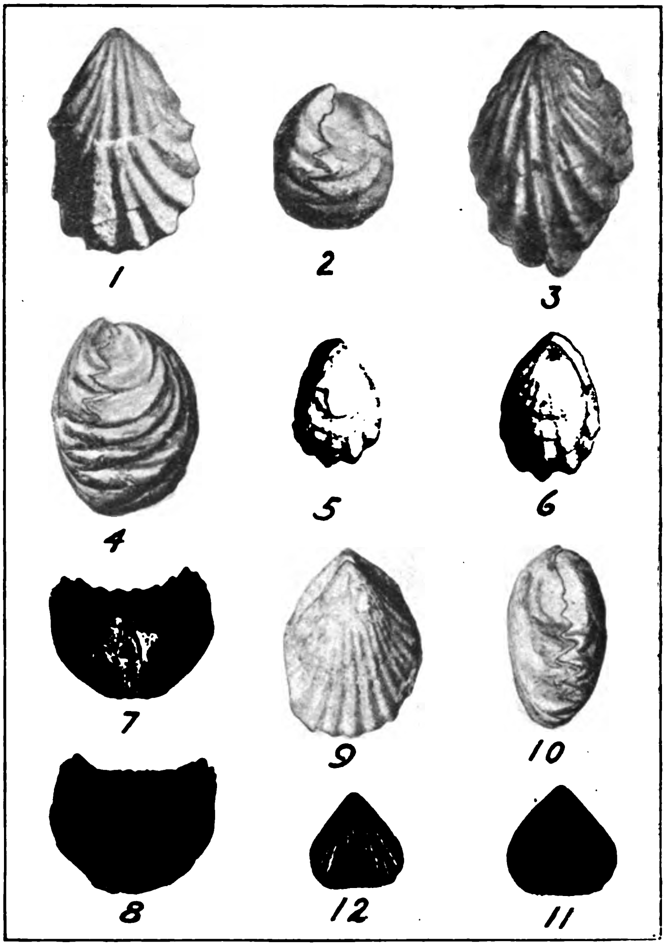
* Monograph U. S. G. S., vol. xxxii, pt. 2, 1899, p. 537, pl. lxix, figs. 1^a, 1^b, 1^c.

Figs. 1–12.



gibbosum, or to the species described by Dr. White* under the name *Rhynchonella caput-testudinis*, we are not in a position to state, nor are we willing to risk the placing of either in the genus *Paraphorhynchus*, since practically nothing is known of their internal structure. However, Dr. White's description of the exterior of his shell would suggest a species of *Paraphorhynchus;* he says "* * * surface marked by from sixteen to eighteen distinct somewhat rounded plications on each valve, which mostly reach the beak with some distinctness, but are occasionally increased both by implantation and bifurcation; they are traversed by fine radiating lines and crossed by fine concentric lines of growth."

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* Proc. Boston Soc. Nat. Hist., 1862, vol. ix, p. 23.

Camarophoria arctirostrata (Swallow). Figs. 11, 12.

Rhynchonella arctirostrata **Swallow, 1863, Trans. Acad. Sci. St. L., Vol. II, page 34.**

This species was described by Prof. Swallow from material collected at Boonville, Mo., from the Keokuk limestone. The original description reads as follows: "Shell triangular or cuneate, valves nearly equal, costate, striate. Ventral valve most convex towards the beak, which is long, pointed, and strongly incurved. Dorsal valve most convex in front; beak small, pointed, and strongly incurved. Both valves flattened in the middle, and bent abruptly near the margins, forming perpendicular subrectangular faces on the sides and one more or less convex and rounded on the front. Each valve marked with from fourteen to sixteen rounded, radiating, plications, which extend to the beak—two or three implanted—and are ornamented by fine longitudinal striæ, and by obsolete concentric folds. The angle at the beak very variable."

Our figures are from specimens collected at the type locality and labeled by Prof. Swallow, being a part of the Boyce collection. Average measurements are as follows: length, 15^{mm}; breadth, 15^{mm}; thickness, 12^{mm}.

The general outline of this species at once recalls *Camarophoria subcuneata* Hall, which fact was noticed by Prof. Swallow, but the peculiar, interrupted, hair-like lines on the plications at once removes the possibility of its belonging to Hall's species. Prof. Swallow's statement that the ribs are ornamented by longitudinal striæ is correct only in a sense, since the striæ are not only interrupted but are also inclined to curve down to the interradial grooves. Sinus and fold obsolete or wanting in this species.

Paraphorhynchus gibbosum sp. nov. Figs. 1–6.

Rhynchonella **sp. Keyes, 1894, Mo. Geol. Surv., Vol. V, pl. xli, figs. 8 a–b.**

Shell elongate-ovate, very gibbous, greatest width at or anterior to the median line, fold and sinus obsolete or wanting in most examples. Valves ornamented with a few coarse ribs, irregular in number and position, increased by implantation and bifurcation, entire surface covered with fine longitudinal striæ, valve margins sharply serrate. Pedicle valve inflated, flattened in the middle, gently curved upwards in the anterior and posterior regions with the posterio-lateral margins inflected, beak somewhat prominent and pointed. Brachial valve decidedly more gibbous than the former, beak less prominent and obscured by that of the opposite valve, posterio-lateral margins inflected or flattened, corresponding with the opposite valve.

This is one of the very rare brachiopods of the Burlington limestone and well preserved specimens are seldom met with; it is only in specimens retaining the exterior uninjured that the delicate longitudinal striæ are to be observed.

Our collection contains specimens from Louisiana, Mo., and Hannibal, Mo., the last being the locality from which Dr. Keyes obtained his specimens. Figures 1, 3, and 4 are of the largest so far observed, measuring: length, 39^{mm}; breadth, 25^{mm}; thickness, 28^{mm}.

Paraphorhynchus ovatum sp. nov. Figs. 9–10.

Shell elongate-ovate, greatest width anterior to the median line, vertically compressed, the transverse diameter always greater than the vertical, fold and sinus obscure, producing only a slight sinuosity in the marginal line. Surface ornamented with eighteen to twenty low rounded ribs, which have their origin near the beak, growing constantly larger as they approach the front; the surface is further ornamented by fine longitudinal striæ, three or four in the space of one millimeter.

Pedicle valve but slightly inflated, sloping gently from the center to the anterior and anterio-lateral margins and somewhat more abruptly to the posterior end; posterio-lateral margins inflected, beak not prominent, incurved. Brachial valve with less depth than the former, subequally sloping and inflected in the posterio-lateral region; beak small and blunt. Average dimensions of the specimens in our collection: 35^{mm} long, 27^{mm} broad and 16^{mm} in thickness, the greatest thickness being in the umbonal region.

Horizon and locality—Chouteau limestone, Kiesenger Bluff, Warsaw, Benton County, Mo.

EXPLANATION OF FIGURES.

Paraphorhynchus gibbosum sp. nov.

Fig. 1. Brachial view of specimen from Hannibal, Mo.
Fig. 2. Profile view of specimen from Hannibal, Mo.
Fig. 3. Brachial view of large specimen from Louisiana, Mo.
Fig. 4. Profile view of specimen from Louisiana, Mo.
Fig. 5. Brachial view of young specimen from Hannibal, Mo.
Fig. 6. Brachial view of specimen from Hannibal, Mo.

Camarophoria ringens (Swallow).

Fig. 7. Posterior view of specimen from New Bloomfield, Mo.
Fig. 8. Anterior view of same.

Paraphorhynchus ovatum sp. nov.

Fig. 9. Brachial view of specimen from Warsaw, Mo.
Fig. 10. Profile view of specimen from Warsaw, Mo.

Camarophoria arctirostrata (Swallow).

Fig. 11. Brachial view of specimen from type locality, Boonville, Mo.
Fig. 12. Pedicle view of somewhat smaller specimen from same locality.

Figures ¾ natural size.

Fulton, Missouri.

ART. VII.—*Descriptions of Tertiary Plants, III;* by T. D. A. COCKERELL.

A SORBUS FROM FLORISSANT, CONSIDERED TO BE A HYBRID.

Sorbus diversifolia (Lx.), fig. 1.

Myrica diversifolia Lx., Cret. and Tert. Flora (1883), p. 148, pl. xxv, f. 6 (not *Cratægus diversifolia* Steud.; not *Pyrus diversifolia* Bong.).

Cratægus acerifolia Lx., Cret. and Tert. Flora, p. 198, pl. xxxvi, f. 10 (not *C. acerifolia* Moench).

Cratægus lesquereuxi Ckll., Bull. Torr. Bot. Club, 33 (1906), p. 311 (not *Sorbus lesquereuxii* Nath.).

Onoclea reducta Ckll., Bull. Am. Mus. Nat. Hist., 24 (1908), p. 76 and 108, pl. vi, f. 4.

THE extraordinarily variable plant to which the above names have been applied is quite common in the Miocene shales of Florissant, at Station 14. A good leaf was also found by my wife at Station 20. In Knowlton's Catalogue (Bull. U. S. Geol. Surv. No. 152) *Myrica diversifolia* is referred as a synonym to *Cratægus flavescens* Newberry (*newberryi* Ckll.); but in his Fossil Flora of the John Day Basin, p. 66, Dr. Knowlton recognizes that while the John Day specimen referred to *Myrica diversifolia* by Lesquereux is undoubtedly *C. flavescens*, the Florissant specimens are doubtfully identical. There occurs at Florissant (Station 14, *W. P. Cockerell*), a species of *Cratægus* which I have provisionally referred to *C. newberryi*, although the leaf is less deeply lobed, and it is not unlikely that the plant is distinct. This, however, has nothing to do with the true *Myrica diversifolia*, which is evidently identical with *Cratægus lesquereuxi*. A comparison of numerous specimens had convinced me that this well-named "*diversifolia*" was a *Pyrus* in the broad sense, and probably a *Sorbus;* but I possessed no material exactly comparable, although I distinctly remembered having seen a similar living plant. During the past summer I was permitted to gather leaves in Kew Gardens, and there at length I found what I had been looking for, labelled *Pyrus pinnatifida* var. *fastigiata*, and *Pyrus neuillyensis*. These trees are hybrids between the *Aucuparia* and *Aria* sections of *Sorbus*. *P. pinnatifida* Ehrh. is properly called *Sorbus hybrida* Linné. It has the apical half of the leaf like *Sorbus intermedia* Pers. (*Pyrus intermedia* Ehrh.), while the basal half is variably cut into leaflets in the manner of the *Aucuparia* group. This occurs in Europe as a natural hybrid (*intermedia* × *aucuparia*).

There is a variety known as *decurrens* Koehne, in which only three to five of the upper leaflets are connate in a terminal lobe, which, like the separate leaflets, is decurrent at the base. Another variety is *S. hybrida* var. *neuillyensis* (Dippel), (*Pyrus neuillyensis* Hort.), of garden origin, having about four pairs of separate leaflets, those of about the apical third connate, but the leaflets not at all decurrent at the base.

A related hybrid is *Sorbus thuringiaca* (Ilse) = *Pyrus thuringiaca* Ilse, with shorter leaves, as might be expected from the parentage, *S. aucuparia* × *aria*. In the fossils, the characters of these hybrids are reproduced with astonishing exactitude. The more common form is similar to *S. hybrida*, but narrower, and as in var. *decurrens*, the divisions are strongly decurrent at the bases, so much so that the leaflets are not wholly separated. In a form which I collected at Station 14 (fig. 1), the lobing extends far toward the apex of the leaf. The form of the petiole, as well as the structure of the blade, is extremely similar in the fossil and recent leaves. Being thus wholly convinced that *Sorbus diversifolia* is a hybrid, I naturally sought for the parents. It was necessary to find in the shale species of the compound-leafed or *Aucuparia* type, and also the dentate, or slightly lobed *Aria* type. The first has already been published as *Sorbus megaphylla* Ckll., Bull. Am. Mus. Nat. Hist., 1908, p. 95, pl. ix, f. 29. The second, at first regarded as a mere variety of *S. diversifolia*, may be described as follows:

FIG. 1.

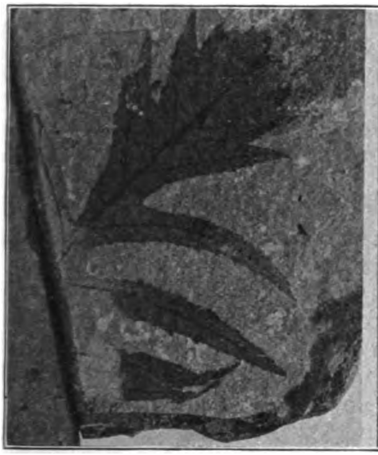

FIG. 1.—*Sorbus diversifolia.*

FIG. 2.

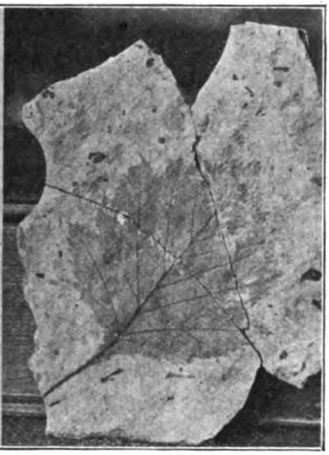

FIG. 2.—*Sorbus nupta.*

Sorbus nupta sp. nov., fig. 2.

Leaf-blade about 67^{mm} long, and nearly as broad, with short triangular lobes, the margin also sharply dentate. Structure and appearance of leaf exceedingly like that of the Italian *S. cratægifolia* (Targ.-Tozz.) Wenzig, except that the Italian plant has the base of the leaf strongly cordate, whereas in the fossil it is strongly though narrowly decurrent on the petiole, extending for a distance of at least 10^{mm}. The strong lateral veins are five or six pairs, as in *S. cratægifolia.* The sharp teeth are perhaps a little more in the manner of *S. latifolia* Syme (*rotundifolia* Auctt.). There is a strong resemblance to *S. intermedia* in the lobing and toothing, but the shape of the leaf is different.

Florissant, in the Miocene shales, Station 13 B (1908).

S. diversifolia is thus considered to be *S. megaphylla* × *nupta.* The only objection to this parentage appears to lie in the fact that *diversifolia* leaves are normally narrower than those of *hybrida,* whereas from the breadth of *S. nupta* one would expect them to be broader.

There is reason to believe that the decurrent base of the leaf is a primitive character; the earliest form of leaf in the *Pyrus* group may perhaps have been narrow-lanceolate, like the living *P. salicifolia* Pall. from the Caucasus, which I had an opportunity of examining in the Cambridge Botanical Garden. From this, *P. amygdaliformis* Vill. (S. Europe) affords a transition to the more ordinary types. The extreme limit of modification is seen in *Sorbus aucuparia* var. *laciniata* (*Pyrus aucuparia* var. *laciniata* Hort. Kew.), in which the leaflets themselves are deeply lobed.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Relative Volatility of the Bromides of Barium and Radium.*—**STOCK** and **HEYNEMANN** have determined the temperatures at which the bromides of calcium, strontium and barium begin to sublime in a quartz tube exhausted by the mercury pump as follows:

Calcium bromide,	about	720° C.
Strontium bromide,	"	770
Barium bromide,	"	820

These results showed that the temperature of sublimation rises with the atomtic weight of the metal in these cases, and it was inferred that barium bromide would sublime more readily than radium bromide. This was found to be the case by fractionally subliming several samples of barium bromide containing varying quantities of radium and determining the radium in the products by the electroscopic method. For instance, a sample gave 8·8 per cent of a sublimate containing 0·008 per cent of radium, while the residue, 88·2 per cent, contained 0·015 per cent of radium. In another case 17 per cent of sublimate contained 4·8 per cent of radium, while the 83 per cent of residue contained 6·6 per cent of radium. The authors are of the opinion that fractional sublimation may be of practical use in the preparation of pure radium salts—*Berichte*, xlii, 4088. H. L. W.

2. *The Action of Light upon Hydrogen Chloride.*—The action of light in causing the combination of hydrogen and chlorine gases is very familiar, hence it is suprising to find from the experiments of **COEHN** and **WASSILJEWA** that ultra-violet light is capable of decomposing hydrochloric acid gas to some extent into hydrogen and chlorine gases. These investigators, having previously found a similar decomposition of SO_3 into SO_2 and O_2, passed pure HCl gas through a quartz tube, where it was exposed to the light of a quartz-mercury=vapor lamp. The gas was then led through a blackened glass tube into potassium iodide solution where the liberation of iodine indicated the formation of chlorine, and the unabsorbed gas, collected in a eudiometer, was shown to be hydrogen. The decomposition of the hydrogen chloride in this way amounted to 0·25 per cent. No decomposition was obtained when tubes of glass, instead of quartz, were used. Any suspicion that the liberation of chlorine here was due to the presence of atmospheric oxygen, which might give the reaction of the Deacon process, $4HCl + O_2 = 2H_2O + 2Cl_2$, was shown to be without foundation since hydrogen was shown to be present.—*Berichte*, xlii, 3183. H. L. W.

3. *The Ratio between Uranium and Radium in Minerals.*—**MLLE. GLEDITSCH** has studied this question, which is important in

connection with the theory of the production of radium by uranium. Other investigators have concluded that this ratio is practically constant, but she has obtained the following results after making corrections for certain sources of error in her method:

	Radium : Uranium
French autunite,	$2 \cdot 85 \times 10^{-7}$
Joachimsthal pitchblende,	$3 \cdot 58 \times 10^{-7}$
Ceylon thorianite,	$4 \cdot 19 \times 10^{-7}$

While these results show magnitudes of the same order, they do not agree closely, and the author concludes that the determination of the mean life of radium based upon the existence of a constant ratio between the uranium and radium in minerals cannot be considered exact.

It may be observed in regard to this conclusion that the author does not appear to take into consideration the possible removal by solution of a part of the radium from the minerals. H. L. W.

4. *The Action of Radium Emanation upon the Elements of the Carbon Group.*—RAMSAY and USHER, using the emanation produced in about a week from 1·2111g. of metallic radium, have caused this to act upon solutions of silicon, titanium, zirconium, thorium, and lead compounds for periods of about four weeks, with the result that they believe that they have proven the production of carbon by this action. The following table shows the amounts of carbon found per cubic millimeter of emanation :

Solution of		Carbon, mg.
H_2SiF_6		0·518
$Ti(SO_4)_2$		0·982
$Zr(SO_4)_2$	I	1·071
	II	0·873
$Th(NO_3)_4$	I	2·93
	II	0·968
$Pb(ClO_3)_2$		0·102

The carbon was found in the form of the dioxide, or as a mixture of this with the monoxide. The amount of CO_2 measured amounted in one case to more than $0 \cdot 5^{cc}$. The authors state that mercurous nitrate gave no trace of carbon dioxide or monoxide, and that similar experiments are being performed with the compounds of other elements.

It is probable that the statement in regard to this production of carbon from other elements will be received with much incredulity, because Sir William Ramsay's previous assertion of the production of lithium from copper in a similar manner was not confirmed.—*Berichte*, xlii, 2930. H. L. W.

5. *Quantitative Chemical Analysis ;* by CLOWES and COLEMAN. 8vo, pp. 584. Philadelphia, 1909 (P. Blakiston's Son & Co.).— This English book, which is also issued in America, has passed through eight editions, with continual improvement and enlargement, since its first appearance in 1891. It gives an introduction

to the subject by describing the general processes and giving an extensive series of simple gravimetric determinations (here called estimations according to the British custom) suitable for the practice of beginners. The more important methods of volumetric analysis are then taken up. The general quantitative analysis covers a wide range of subjects, largely technical in character; the analysis of ores, metals, alloys, fuels, fertilizers and other products. It takes up also fire assaying, sanitary water analysis, the analysis of milk, butter, alcoholic beverages, sugar, tea, tanning materials, soap, oils, fats and waxes, and technical gas analysis. One section of the book is devoted to ultimate organic analysis and molecular weight determinations. Although some of the topics are necessarily treated rather briefly and incompletely, the book is an excellent one for giving the student practice in nearly all of the usual work of the analytical chemist. The methods are generally well selected and clearly described, but there are naturally some variations between the British practice here given and what may be called the best American practice in analysis. The book has found extensive use as a text-book, and the new edition will doubtless be still more popular. H. L. W.

6. *Positive Electricity*—Sir J. J. THOMSON asks:—(1) Does a definite unit of positive electricity exist? (2) If so, what is the size of the unit? This paper introduces a discussion upon these questions at the Winnipeg meeting of the British Association and therefore contains matter previously printed. There are, however, some new experiments upon the effect of magnetic fields on positive and negative rays, which led the author to elaborate theories in regard to neutral doublets. He concludes that even at the start from the cathode the "canal strahlen" include a large number of neutral doublets, if indeed they do not wholly consist of them. Much space is given to discussion of the neutral doublets, both in canal strahlen and retrograde rays, which proceed from the cathode toward the anode. It is supposed that these doublets are of the same character from whatever kind of gas they originate. Thomson refers to a former paper in which he showed that if a vessel was exhausted until the pressure was so low that the discharge would not pass, and small quantities of hydrogen, helium, air, oxygen, carbonic acid or argon were introduced so as to raise the pressure sufficiently to produce a discharge, the velocities of the particles were the same for all the gases. The paper closes with description of a method of measuring the effective magnetic field in the magnetic deflection of canal strahlen.—*Phil. Mag.*, Dec. 1909, pp. 821–845. J. T.

7. *Doppler Effect in Positive Rays in Hydrogen.*—T. ROYDS has studied this effect, both in front and behind the cathode. He believes that the canal rays mostly start from the negative glow, and believes that the commencement of the cathode glow corresponds to the minimum Doppler effect when the cathode is viewed from

the anode side. After twenty hours exposure with a cathode fall of 2800 volts, he obtained a marked Doppler effect corresponding to the positive rays approaching the cathode. This minimum velocity is not constant for different wave lengths, but is approximately inversely proportional to the square root of the wave length.—*Phil. Mag.*, Dec. 1909, pp. 895–900. J. T.

8. *Magnetic Rotation of Plane of Polarisation in the Ultra-red.*—Many investigations have been undertaken to put Faraday's experiment on a sound theoretical basis. Voigt has placed all such investigations in two classes, and the author of this paper, Ulfilas Meyer, discusses Drude's theories, which are largely based upon the electron theory. He finds that with crystals of fluorspar, sylvin and rock salt, the amount of the turning of the plane of polarization diminishes with increasing wave length. At 8·85 μ it is less than a minute for a thickness of the crystal of 1^{cm} and a field strength of 10,000 Gauss units. The influence of ions on this turning is very small in comparison to that of the ions. This conclusion is reached from the ground of Drude's view of the electron theory, according to which ultra-red absorbtion arises from vibrating ions, while ultra-violet is excited by resonance of rotating electrons.—*Ann. der Physik*, No. 132, 1909, pp. 607–630. J. T.

9. *Instantaneous X-ray photography.*—FRIEDRICH DESSAUER states the desirability of shortening the time of exposure to X-rays, and describes a powerful apparatus which he has devised for this purpose. It consists of a very large induction coil, fed by a powerful current which on arising to a proper value is quickly broken by a peculiarly constructed fuse. This fuse is a calibrated piece of wire which is surrounded by a moist covering consisting of a mixture of earths. When the wire heats, the water vapor is formed quickly under pressure and the fuse explodes with violence, breaking the current. The author recommends his method to physicians and has obtained Röntgen cinematographs of the movement of the heart.—*Physikalische Zeitschrift*, Nov. 10, 1909, pp. 859–860. J. T.

10. *Light and Sound;* by WM. S. FRANKLIN and BARRY MACNUTT. Pp. viii, 344. New York, 1909 (The Macmillan Co.).—This volume is a part of a series of elementary texts; practically a revision of Nichols and Franklin's Elements of Physics, which it is doubtless designed to replace. The present volume is the third of the new set: Mechanics having appeared in 1907, Electricity and Magnetism in 1908 and Heat being in course of preparation. Improvement is noted in the relegation to an appendix of the more detailed discussion of lens systems, of radiation and the addition of 86 problems as exercises on the several chapters. An excellent discussion of wave motion in general is illustrated by particular waves in water. A total of 143 pages have been added. Much of the additional matter pertains to practical applications, on the importance of which to elementary students the authors express their opinion in the

following words:—"A so called knowledge of elementary science which does not relate to some actual physical condition or thing is superlatively contemptible." D. A. K.

11. *Direct and Alternating Current Testing;* by FREDERICK BEDELL; assisted by CLARENCE A. PIERCE. Pp. x, 265. New York, 1909 (D. Van Nostrand Co.).—To call this book a laboratory manual of tests on direct and alternating currents, would not be doing it justice. The consideration given to the underlying principles of the experiments, as well as to the significance of the results, places it both in the category of reference and of text books. It is not offered as an exhaustive treatment of the subject but is sufficiently comprehensive to give the student a good working knowledge. It presupposes only the usual college courses in physical and electrical measurements. The subjects of the seven chapters are :- D.C. generators; D.C. motors; synchronous alternators; single phase currents; transformers; polyphase currents; phase changers, potential regulators, etc. Other chapters on A.C. motors and converters are promised in a later edition. D. A. K.

12. *Elements of Physics;* by HENRY CREW. Revised by FRANKLIN T. JONES. Pp. xiv, 435. New York 1909 (The Macmillan Co.).—This high school text is a revision of Crew's original Elements of Physics and embodies much of his more recent General Physics. The insides of the covers contain the English and Metric systems of weights and measures, with tables of their equivalents. In the appendix are given 370 questions reproduced from examination papers of various high schools throughout the country. Definitions and leading statements are emphasised by bold-faced type, and numerous problems are embodied in the text. It is to be hoped that in the next edition the authors may eliminate such slips as "knots per hr.," "attraction of gravity, g," "in physics rate always means 'divided by time'", and revise the somewhat misleading discussion of harmonic motion. D. A. K.

II. GEOLOGY

1. *Radio-activity and Geology. An account of the influence of radio-active energy on terrestrial history;* by J. JOLY. Pp. 287. London, 1909 (Archibald Constable & Co., Ltd.).—This book is an outgrowth of the author's presidential address to Section C of the British Association and brings into one volume the present information regarding radio-activity in its bearings on geology. Geologists will consequently find it a most welcome volume since but few have the time or opportunity to follow in the physical journals the rapidly accumulating results of recent investigations.

The first larger subject treated is that of radium in the earth's surface materials. Many measurements have now been made on igneous and sedimentary rocks. The amount of radium varies, however, within wide limits, the abyssal radiolarian ooze and red clay being especially high. As radium loses half its mass in 1760 years while its ultimate parent uranium takes five billion years for the same loss, it is seen that the radium in the rocks is really a measure of the contained uranium. Strutt, extending the work of Rutherford, has shown that the radio-active materials in the crust exist in sufficient abundance so that a crustal layer less than 100 miles in thickness would continually supply the quantity of heat which the earth loses to space (45 miles in the original estimate). Joly argues, therefore, that the uranium must be concentrated in the outer crust of the earth. Consequently where this concentrated zone is depressed by the accumulating sediments of a geosyncline, the loss by conduction being lessened, the temperature must rise. Local excesses as in the Simplon tunnel are also thought to play an important part in determining local temperature gradients. Joly further argues that the instability of the earth's crust and the ocean floor are also due chiefly to uranium and radium becoming more deeply buried.

Another chapter of great geological interest is that on uranium and the age of the earth. Considering helium and lead as the ultimate disintegration products of uranium, measurements of their amounts in uranium minerals, while varying among themselves and pointing to the need of further research, agree in giving much larger values to geological time than estimates based upon denudation and sedimentation.

Throughout the volume, the author, while arguing for the large influence of radio-activity, shows a spirit of fairness and caution. But there is room for so many possibilities in the underearth, which he does not discuss, that a large degree of skepticism may be maintained toward many of his conclusions. Of the geological importance of radio-activity there can be no doubt and it seems adequate to more than account for the temperature gradient, so that instead of a cooling earth we may come to face the possibility of a heating earth. But the deep-seated distributions of energy, pressure and mass traceable to earth origin, whatever that may be, seem able to play the chief part in terrestrial dynamics without invoking the radio-activity of the outer crust as a controlling cause. The contributions of various writers, but more notably Chamberlin, show the weakness of the outer zone to generate compressive movements, which seem, on the contrary, to be initiated by shrinkage of the centrosphere, periodically producing collapse of a thick outer shell of the earth. The great vertical movements, on the other hand, as shown by investigations on isostacy, seem to be in their origin largely independent of denudation and sedimentation, but dependent upon differential volume changes in the outer hundred miles. The isostatic adjustments are further without doubt modified by surface unloading and loading. These considerations are not adequately discussed by Joly.

To make the foregoing criticisms specific by citing an illustrative point: it is inferred by Joly that uranium is concentrated in the outer hundred miles of the crust because if it extended indefinitely downward in the same amount, the energy liberated would be more than sufficient to maintain the temperature gradient. This inference, however, has no supporting evidence and leads in turn to some assumption as to the manner in which uranium could be so concentrated and yet remain in its extremely diffused state. On this inference of the subsurface concentration is nevertheless based an explanation of the making of mountains and of continental and oceanic movements. As other allowable inferences which would meet the same condition of a subsurface excess in radio-activity, it may be suggested that in the deep body of the earth the pressures and temperatures, greater than any attainable in the laboratory, may partially or completely inhibit the radio-active degradation of uranium, or offsetting heat-absorbing reactions in other materials may take place, or igneous activity may serve as a safety valve to reduce the excess of internal energy transmuted from subatomic to atomic form. These are all speculations which have not been disproved. None of them may be true, but they indicate the danger of arriving at conclusions supported on a complicated superstructure of reasoning when the stability of the foundation premises is open to serious question. In considering the problems connected with internal terrestrial activities the field of the unknown is so large that the method of multiple working hypotheses should be more largely employed than is done in this volume. Nevertheless much is brought out which is stimulating and suggestive. J. B.

2. *The Geology and Ore Deposits of Goldfield, Nevada;* by F. L. Ransome. U. S. G. S., Prof. Paper No. 66, pp. 253, 35 plates, 34 text fig. Washington, 1909.—The Goldfield district consists essentially of a low, domical uplift of Tertiary lavas and lake sediments resting upon a foundation of ancient granite and metamorphic rocks. The erosion of this flat dome has exposed the pre-Tertiary rocks at a number of places in the central part of the district, and these outcrops are surrounded by wide concentric zones of successively younger formations. Some of the later lavas were erupted after the dome had been elevated and truncated. The pre-Tertiary rocks consist to-day of quartz rocks intruded by masses of a granitic rock like that to which the name alaskite has been given. The Tertiary lavas include dolerite, rhyolite, basalt, andesite and latite. Most of these are found in different flows of different periods and lying between them are various fragmental rocks.

The sulphide ores of the Goldfield district are of complex mineralogical character, native gold and pyrite being accompanied by minerals containing copper, silver, antimony, arsenic, bismuth, tellurium, and other elements. In some ores the gold occurs free in fine particles, which, as a rule, are aggregated together to form yellow bands or blotches. The associated minerals are pyrite, marcasite, bismuthinite, perhaps famatinite, and a new cupric sulphantimonite, which has been named goldfieldite. (See below.)

The most notable features of these ore bodies are their remarkable richness and their equally remarkable irregularity. The ores are associated with craggy outcrops of silicified, volcanic rock. Associated with the silicification other processes of locally intense alteration, especially the formation of alunite, have also been active. The deposits have formed along irregular and branching zones of fissuring. The surface ores were oxidized and furnished a large part of the gold during the first years of exploitation.

GOLDFIELDITE occurs as a gray material in a dark telluric crust found at the Mohawk mine. The material was crushed and picked over under a lens. The gray portion appeared homogeneous, with the exception of a few minute specks of gold. Color, dark lead-gray, with a high metallic luster. Brittle. Conchoidal fracture. Hardness = 3 — 3·5. No crystal faces noted. Analysis by Palmer on small amount of material gave :

Cu	S	Te	Sb	As	Bi	Au	Ag	Gangue
33·49	21·54	17·00	19·26	0·68	6·91	0·51	0·18	2·00 = 101·57

The mineral is considered to be a cupric sulphantimonite, in which part of the antimony is replaced by arsenic and bismuth and part of the sulphur by tellurium. Formula derived is $5CuS.(Sb,Bi,As)_2(S,Te)_3$.

It would seem, in view of the facts presented concerning this substance, that the giving to the material a name and rank as a new species is hardly warranted. The material was intimately mingled with other minerals and had to be crushed and picked over by hand, so that the purity of the material analyzed must be somewhat questioned. It showed no crystal forms. The analysis was made on a small amount of material, and shows a high summation, and the formula derived is only approximately justified by the analysis. It would seem desirable that more positive proof should be given before we can assume the existence of such an unusual compound as a *cupric* sulphantimonite.

W. E. F.

3. *United States Geological Survey; Issue of Geologic Folios in pocket form.*—The Geological Survey has recently inaugurated the publication of an edition of the Folios of the Geologic Atlas of the United States in octavo form convenient for field use. The maps are folded and enclosed in a pocket so that the whole, including the accompanying text, forms a pamphlet of about 6 x 9 inches. The folio form will also be continued, as it is most satisfactory for office and library use, but the new pocket edition will be welcomed by those at work in the field. The Folio now received is No. 167 of the series, and describes the Trenton, New Jersey-Pennsylvania Quadrangle ; it is stated that the five folios, No. 164–168, have been printed and are ready for distribution in this new form. It is also to be noted that henceforth the separate maps, unfolded, showing the areal geology of the

Quadrangle, will be, when desired, furnished separately at the nominal cost of five cents each.

4. *Geological Survey of West Australia.*—The following publications have recently been received:

Annual Progress Report for the year 1908. Pp. 19, 3 maps.

Bulletin No. 32, containing: Greenbushes Tinfield, by A. Gibb Maitland, A. Montgomery, W. D. Campbell, and Mr. E. S. Simpson. Pp. 75, 2 plates, and 7 photos. Mount Malcolm Copper Mine, by Harry P. Woodward. Pp. 8, 1 plate. Fraser's Gold Mine, Southern Cross, by Harry P. Woodward. Pp. 6, 1 map, 1 plate.

Bulletin No. 35, containing Geological Report upon the Gold and Copper Deposits of the Phillips River Goldfield, by Harry P. Woodward. Pp. 104, 2 maps, 8 plates, 7 photos.

Phosphate deposits have been discovered near Christmas Island, where a layer of phosphatic travertine 153,600 square yards in area and with a thickness of two feet has been investigated. The travertine is believed to owe its origin to capillary attraction, drawing up ground water from the lime contained in the underlying sands. In an investigation of the Green Bushes Tinfield (Bulletin 32) examination was necessarily made of the laterite of this region, which has a wide distribution and varies in composition from solid and pure limonite to aluminous rocks almost destitute of iron and often so tough that explosives have little effect. The distribution and character of the laterite in the Green Bushes region "clearly indicates periodic and zonal changes in the climatic conditions." In connection with the petrographic description of the crystalline rocks of the Phillips River (Bulletin 35) analyses were made of the following types: soda-granite, spodumene, albite, and eclogite. H. E. G.

5. *Contribuzioni allo Studio Petrographico della Colonia Eritrea;* by E. Manasse. 4°, pp. 168, 8 plates and map. Siena, 1909.—This work is based upon the collection of rocks made by Profs. G. Dainelli and O. Marinelli during their geological researches in the Italian colony of Erythrea, East Africa, in 1905–1906. After a brief sketch of the geology of the area visited, the main body of the work is devoted to a detailed report of the results of a thorough petrographical study of the specimens. The author first describes, rather briefly, a series of schists of various kinds, including some porphyroid, mica schists, amphibolites, gneisses, etc. Then the igneous rocks are treated, and these were found to consist of granites, some of which, as shown by the analyses, are of alkalic character with predominant soda; diorites of several types; a hornblendite which is a local facies of diorite, and two specimens of teschenite. There are also dike rocks, granite and diorite prophyries, aplites, paisanite, bostonite, tinguaite, malchites and among the lamprophyres, kersantites and camptonites. The effusive rocks or lavas are also not wanting and include quartz porphyry, rhyolite and rhyolitic tuffs, obsidians and pumices. Dacite and a great variety of

basalts close the list. In the sedimentary rocks are found sandstones, argillites, limestones, travertine, etc. The work closes with a chapter dealing with various generalizations on the results obtained. It is illustrated by a large number of excellent photogravures made from microphotographs of the thin sections studied. Its value is also much enhanced by a large number of excellent chemical analyses of the various rocks, which are the result of much patient labor in the laboratory.

The work is an excellent contribution to our knowledge of East African petrology, and it is interesting to observe that the nature of the rocks is in harmony with the general alkalic character of the East African petrological province, as shown by a number of investigators during the last few years. L. V. P.

6. *Carboniferous Air-breathing Vertebrates of the United States National Museum ;* by ROY L. MOODIE. Proc. U. S. Nat. Mus., vol. 37, pp. 11–28, with pls. 4–10.—This paper, the fifth of Dr. Moodie's contributions to our knowledge of the early Amphibia, is a result of the study of a small collection in the National Museum ; but one which is of great interest in that it contains the only known examples of scaled Amphibia from North America, as well as the only known specimen of a Carboniferous reptile from the Allegheny series. This reptile, *Isodectes punctulatus* Cope, Doctor Moodie thinks, shows certain aquatic as well as terrestrial adaptations ; the former being the broad-surfaced foot, such as MacGregor has described in *Mesosaurus brasiliensis.* The affinities of Isodectes are close to the Microsauria among the Amphibia ; to what group of reptiles it is related is not known.

Of the Microsauria, Moodie describes some 17 species and 15 genera, of which 3 of the former and 1 of the latter are new. The material comes in part from Linton, Ohio, and Cannelton, Pennsylvania. R. S. L.

7. *Cenozoic Mammal horizons of Western North America,* by HENRY FAIRFIELD OSBORN ; *with Faunal Lists of the Tertiary of the West,* by WILLIAM DILLER MATTHEW. Bull. U. S. Geol. Survey No. 361, 1909, pp. 1–138, with 15 text figs. and 3 plates.—For the student of faunal paleontology as well as the stratigraphical geologist this paper is of the utmost importance, containing as it does a bibliography, a general discussion of the geologic and climatic history of the Tertiary, a careful description of the successive faunal phases, and most comprehensive faunal lists of the Tertiary mammals.

The principal facts established are the two great natural divisions of geologic deposition and of habitat, the mountains and the plains; the progressive aridity of the climate during the Cenozoic with its consequent soil denudation and deforestation, and the destruction of most of the larger forms of life during the lower Pleistocene glacial epoch. The contrast of the mountain and plains regions are no less striking than their resemblances. In the mountain region, with some exceptions, the drainage systems are the same to-day as in the Tertiary, while on the plains the rivers are comparatively modern. In the mountains from the Basal Eocene to the John Day the rocks are not worked over, as erosion was retarded by the heavy cappings of lava in the John Day basin of Oregon, in the Bridger basin by a dense Pleistocene (?) conglomerate and in the Washakie by a fine conglomerate.

In the plains region, by contrast, the very extensive Oligocene strata were in part worked over to form the Miocene and these in turn to form the Pliocene; all three contributed to the Pleistocene, and all four are now contributing to the alluvium of the Great Plains.

The successive faunal phases are:—

1, Archaic Mesozoic mammals with partly South American, partly European affinities. Basal Eocene.

2, The first modernization, invasion of the archaic by the modern fauna—whence is not surely known, but Osborn favors a North American-Asiatic or Holarctic origin; the severance of the South American land connection—Initial elimination of the archaic fauna in competition with the modern. Wasatch.

3, Absence of fresh Eurasiatic migration, descendants of archaic and modern mammals slowly evolving and competing, with the gradual elimination of the archaic. Establishment of the North American Artiodactyla. Wind River to close of Mocene.

4, Second modernization—First knowledge of the plains fauna—Absence of all archaic mammalia except the Hyænodontidæ—Reëstablishment of faunal resemblances with western Europe. Oligocene and Lower Miocene.

5, Fresh migrations from Europe. First proboscidians and true Felinæ. Middle Miocene to Lower Pliocene.

6, Land connection with South America. Intermigration of North and South American mammals. Middle and Upper Pliocene.

7 Increasing cold, moisture and forestation. Third modernization by Eurasiatic invasion—Gradual extinction of larger Ungulata. Pleistocene.

Conclusion:—North America promises to give us a nearly complete and unbroken history of the Tertiary in certain regions, which are, after all, comparatively restricted. Middle and Upper Eocene are approaching solution; Lower and Basal Eocene still require additional surveys. The chief remaining gap is now in the Pliocene stratigraphy, materials being at hand for an establishment of the Pleistocene sequence. R. S. L.

8. *New Fossil Mammals from the Fayûm Oligocene, Egypt;* by HENRY FAIRFIELD OSBORN. Bull. Amer. Mus. Nat. Hist., vol. xxiv, 1908, pp. 265–272, with 6 text figures.

New Carnivorous Mammals from the Fayûm Oligocene, Egypt; by H. F. OSBORN. Ibid., vol. xxvi, 1909, pp. 415–424 and 9 text figures.—In these two papers Professor Osborn describes part of the remarkable wealth of material collected in the Fayûm by the expedition from the American Museum sent out during the winter of 1906–1907. The first paper contains descriptions of two new genera of uncertain ordinal position as well as two new genera of rodents, including in all an equal number of species. In the second paper a number of creodont genera and species are described, all referable to the Hyænodontidæ, the last surviving family of the order. R. S. L.

9. *New or little known Titanotheres from the Eocene and the Oligocene;* by HENRY FAIRFIELD OSBORN, Bull. Amer. Mus. Nat. Hist., vol. xxiv, 1908, pp. 599–617 with 21 figures in the text.

"In the preparation of the U. S. Geological Survey monograph 'The Titanotheres' the collections of Eocene and Oligocene materials in the larger museums of the country have been reviewed with care. Like the Oligocene titanotheres previously reviewed, the Eocene titanotheres prove to be in a high degree polyphyletic." From the Wind River formation are two genera and three species; from the Lower Bridger one genus and three species; from the Upper Bridger and Lower Washakie three genera and five species; from the Upper Washakie and Lower Uinta two genera and four species; from the Upper Uinta two genera and three species, and finally from the White River Oligocene two new genera, each with a single species, are described.

Dolichorinus hyognathus, of which the more familiar name, *Telmatotherium cornutum*, is a synonym, is restored in the skeleton and gives a good idea of the appearance of one of these ancestral titanotheres. R. S. L.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Autobiography of Nathaniel Southgate Shaler*, with a supplementary Memoir by his wife. Pp. 481, with 16 illustrations. Boston and New York, 1909 (The Houghton Mifflin Company).—The six or seven thousand students who heard Shaler's lectures at Harvard during his forty years service were always deeply impressed with his personality, his wide experience of men and the world, and his vivid presentation of the principles of geology, enlivened by ever-flowing narrative of pertinent incidents, all the more entertaining from being phrased in picturesque language. The personality of the man is strikingly presented in this volume, of which the first half, descriptive of his youth up to the beginning of the Civil War, comes from Shaler's own pencil—for it was his habit to prepare manuscript with pencil rather than with pen—while the second half, descriptive of his more mature years, is written by his wife. The picture that we gain of the way in which science was studied at Harvard under Agassiz is particularly interesting; a way that was well fitted for youths of the strong individuality that Shaler possessed. Several chapters on excursions along the coast of Maine and farther down east, with Hyatt, Stimpson, Verrill and others, are of special interest as

illustrating the delightfully primitive conditions of scientific exploration in the early sixties; they show the richness of happenings even on a near-by coast, if one only has the knack of meeting them as Shaler always had.

The memoir by Mrs. Shaler exhibits the extraordinary variety of relations into which Shaler entered after his return to Harvard at the close of the war. It includes accounts of his several journeys abroad, where he made personal acquaintance with the leading geologists of the time; of his work on the Kentucky State Geological Survey and on the Coast Survey; of his occasional westward journeys chiefly in connection with mining interests; of his wide excursions in literary fields, reflected again in the list of publications at the end of the volume; and above all of the innumerable activities at Harvard which made him, as William James put it, "the myriad-minded and multiple-personalitied embodiment of all academic and extra-academic *Kenntnisse* and *Gemüthsbewegungen.*" The real worth of this book lies in the deep impression that it gives of the value of personality as compared to mere learning. W. M. D.

2. *Third Report of the Wellcome Research Laboratories at the Gordon Memorial College, Khartoum;* ANDREW BALFOUR, Director. Published for the Department of Education, Sudan Government, Khartoum. Pp. 477, with 28 colored plates, 413 reproductions of drawings and photographs, and 19 maps and plans. London, 1908 (Baillière, Tindall & Cox); New York (Toga Publishing Co., 45 Lafayette St.).—This handsome volume shows the latest work of the enthusiastic investigators at this now famous tropical laboratory. As in the earlier reports, noticed in this Journal, the work covers a wide field of investigation, although such biological topics as concern the health of the natives are given a prominent position.

The blood parasites of man, domestic animals, rats, birds, reptiles, and fishes of the region have been subjected to extensive investigations by the director of the laboratory, and by Dr. Wenyon, both of whom contribute several beautifully illustrated reports, which form important contributions to the knowledge of these important parasites. The sanitary conditions existing in Khartoum are discussed, and further observations on sleeping sickness, kala-azar, and other diseases reported. Poisonous snakes and other reptiles have been studied by specialists, the parasitic worms investigated, and the insects of economic importance discussed and illustrated by colored plates.

The later chapters deal with well illustrated articles on the healing art as practiced by the dervishes, the physical characters of certain negroid tribes, and notes on ethnographical specimens, while the reports of chemical investigations at the laboratory conclude the work. The floating laboratory on the Jurriver has proved a marked success.

The admirable courage shown by those who have made these investigations, under the most trying climatic conditions, has been further tested by a recent fire which destroyed many of the important preparations and documents at the laboratory. W. R. C.

3. *Illustrations of African Blood-sucking Flies other than Mosquitoes and Tsetse-flies;* by ERNEST EDWARD AUSTIN. Pp. xv, 221, with 13 colored plates. London, 1909 (British Museum of Natural History).—Since the discovery that many of the most fatal diseases of man and animals are disseminated by means of the bites of blood-sucking flies, the British Museum has published a number of handsomely illustrated monographs on various groups of these insects. Belonging to this series is the present volume, which gives general and non-technical descriptions and excellent colored figures of 103 African species, all of which have blood-sucking habits, although it is not yet known which of them may serve in spreading diseases. W. R. C.

4. *The Cambridge Natural History;* edited by HARMER and SHIPLEY. Vol. IV. Crustacea and Arachnida. Pp. xviii, 566, with 286 figures. London 1909 (Macmillan & Co.).—The series of ten volumes of excellent treatises by specialists in the different groups of the animal kingdom is now complete, and forms perhaps the most convenient and generally useful work of reference on the subject that has appeared in the English language in recent years.

The present volume is quite up to the high standard of the others of the series, and treats of the Crustacea, and the widely divergent forms, as king crabs, spiders, scorpions, ticks, mites, water-bears, pycnogonids, and other animals, both fossil and living, which are now generally grouped together as Arachnida. The contributors for this volume are Geoffrey Smith, Henry Woods, A. E. Shipley, Cecil Warburton and D'Arcy W. Thompson. The general excellence of the text is shared by the numerous illustrations. W. R. C.

5. *The Human Body and Health: An Intermediate Text-Book of Essential Physiology, Applied Hygiene, and Practical Sanitation for Schools;* by ALVIN DAVISON. Pp. 223, with 150 illustrations. New York, 1909 (American Book Company).—The aim of this little book is to give the pupil in the public school a general knowledge of the principles of personal and public hygiene. Such of the essentials of the anatomy and physiology of the human body as it is necessary to introduce are clearly described and illustrated. W. R. C.

6. *International Congress of Radiology and Electricity.*—It is announced that an International Congress of Radiology and Electricity will be held in Brussels in 1910 under the patronage of the Belgian government and of the French Physical Society. A provisional program has been issued; the address of the General Secretary is 1 Rue de la Prévôté, Brussels.

New Circulars.

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rof. W. G. Farlow.

VOL. XXIX. FEBRUARY, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

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FOURTH SERIES

VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

No. 170—FEBRUARY, 1910.

WITH PLATE I.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the **Postal Union; $6.25 to Canada.** Remittances should be made either by money orders, **registered letters, or bank** checks (preferably on New York banks).

BRIEF
ANNOUNCEMENTS.

Recent pressure of business has hindered me from compiling a detailed list of new minerals arrived. I wish to mention, however, a new lot of the metallic Awaruite from Smith River, California, ranging in sizes from ¼ inch to 1 inch. These interesting metallic pebbles are of scientific value on account of the nickel being associated with the iron in the metallic state. Considering the great amount of attrition which they received from stream action, I find them very well preserved and deserving a place in every collector's cabinet. These range in price from 25 cents to $2.00.

Although the finest of the recent Iceland Zeolites and Franklin Furnace minerals have been sold off rapidly, I still have choice examples of these splendid specimens at reasonable prices.

Having received some excellent shipments representing chiefly Hungary, Saxony and other celebrated German localities, of which specimens I was unable to prepare a list in time for this issue, I shall be pleased to furnish further data on request. I noted in these shipments several specimens of the rare Argyrodite and other silver minerals too numerous to mention.

I recently received additional minerals from Colorado and can now supply any reasonable demand in Tellurides, native Tellurium, Amethystin-Quartz, Calciovolborthite and Carnotites. Prices on request.

I have also considerably increased my stock of the celebrated California Tourmalines so that I now feel that no dealer has ever had the quality and quantity of these specimens that I have, while the prices of same have been somewhat lowered, considering their value, as compared with former prices.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII.—*The Nitrogen Thermometer from Zinc to Palladium;* by ARTHUR L. DAY and ROBERT B. SOSMAN; with an Investigation of the Metals, by EUGENE T. ALLEN.

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1. *Introduction and Plan.*

THE measurements of absolute temperature here offered were undertaken in direct continuation of those published from the Geophysical Laboratory two years ago,* with the purpose of extending the gas scale to 1600°, or as near it as might prove practicable. Except in explanations of new or particularly important features, descriptive details have accordingly been omitted here and must be sought in the first paper. Substantially the same methods and apparatus have been employed throughout.

One conclusion in particular which was brought out at that time is entitled to even greater emphasis, namely, that the existing uncertainties in the absolute temperature scale at 1000° and above are the result of experimental limitations and not of any failure of the principles involved. The experimental conditions were scrutinized with great care throughout the first investigation, and not only were the known correction factors all redetermined, but their total magnitude was reduced nearly 75 per cent. This success, after so long and painstaking a study of the correction factors, led the authors to believe that the upper end of the existing gas scale (melting point of pure copper), which has been vacillating in a somewhat irregular way in various hands for three-quarters of a century, had been finally confined to the limits ± 0·5°, or within 1°. Although this ideal had been affectionately cherished for a good many years, its triumph has been shortlived. The present investigation has discovered a source of error which appears to have passsed unnoticed before, which operates to raise the temperature scale at the copper point about 1·4°. This kind of history has repeated itself with remarkable persistence all through the record of high temperature research, and may, of course, do so again, but the limits of uncertainty are continually becoming narrower, and it appears to the authors unlikely that further investigation will again reveal errors aggregating 1°.

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* Arthur L. Day and J. K. Clement, this Journal (4), xxvi, 405–463, 1908.

On the other hand, the detailed study of temperature distribution about the bulb (page 102) in which the present error was discovered, cannot but convince an experienced observer that the limit of refinement in an electrically heated air bath has been practically attained, and that higher accuracy in gas thermometry must be sought in a liquid bath which can be stirred.

Since the publication of the Reichsanstalt scale* in 1900, it has remained the standard for all temperature measurements between 400° and 1100°. Its limit of accuracy as an absolute scale was estimated to be about 3° at 1000°.

The work of Day and Clement was mainly directed to the following essential features of the problem of absolute measurement with a constant volume gas thermometer: (1) An absolutely gas-tight bulb of definite volume; (2) uniform distribution of temperature over the bulb surface during the measurements; (3) the reduction of the error due to the unheated capillary tube connecting the bulb with the manometer; (4) a more accurate determination of the expansion coefficient of the bulb itself.

The results accomplished by them in these directions may be outlined seriatim as follows: (1) The bulb chosen (90 parts platinum, 10 parts iridium) is quite rugged enough for measurements as high as 1500°, and no difficulty was experienced in maintaining a nitrogen atmosphere in it without loss by diffusion or leakage. At high temperatures the material becomes considerably softer, but with the help of a gas-tight furnace in which nitrogen could be maintained at the same pressure outside the bulb as within, neither diffusion through the bulb walls nor mechanical strain was encountered. Variations in the zero point of the thermometer, which have been very persistent and inaccessible errors throughout the history of gas thermometry, have therefore now become practically negligible. This gas-tight furnace possessed the further advantage that the initial pressure of the gas, and consequently the sensitiveness of the instrument, could be varied within considerable limits. A sensitiveness as great as 1^{mm} of the manometer scale per degree was regularly employed. The iridium alloy has the disadvantage that platinum thermoelements, which are necessary for recording variations in the temperature over the surface of the bulb, and for transferring the gas thermometer temperatures to standard melting points, become contaminated in the presence of iridium at all temperatures above 900° C.; the higher the temperature and the longer the time of exposure, the greater the degree of contamination.

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* L. Holborn and A. L. Day, Ann. d. Phys. (4), ii, 505, 1900; this Journal, (4), x, 171, 1900.

(2) It was sought to obtain a uniform temperature over the surface of the bulb by winding the (pure platinum) furnace coil on the inside of a refractory magnesia tube which contained sufficient iron oxide and other impurities to be a fairly good conductor of heat. The winding was somewhat closer at the ends than in the middle. This was further supplemented by secondary coils of smaller wire extending a few centimeters into the tube from each end. The current in the three coils could be independently regulated with the help of thermoelements attached to the bulb and giving its temperature at the middle and upon each shoulder (positions 2, 4, and 6, fig. 1). When these temperatures had been adjusted so that the differences between them were smaller than 0·5°, it was assumed that the temperature over the whole surface of the bulb was constant within those limits. (For the oversight in this assumption, see pages 99 and 102.)

(3) The platinum capillary and connections between the bulb and the manometer were much diminished in volume. Compared with the total volume of the bulb ($195{\cdot}7^{cc}$) this connecting volume amounted to ·0015 in their instrument, and reduced the total correction for the "unheated space" to less than 5° at 1100°, a correction factor not more than one-fourth as large as the best previous attainment in this direction. The uncertainty of the temperature distribution in the "unheated space" was perhaps 10 per cent, making the probable error from this source about 0·50°.

(4) A special bar 25^{cm} in length, made up from the same alloy as the bulb, was provided with a scale and its length measured in a special form of comparator at temperature intervals of 50° up to 1000°. The expansion was found to be $10^6\beta = 8{\cdot}84 + 0{\cdot}00131t$, with an error of about 0·5 per cent. An irregularity was detected both in the expansion and subsequent contraction in the region below 300°, which appeared variable with the rate of cooling or heating, and in character resembled the hysteresis which appears in a bar which has been subjected

to stress. If the bar was cooled down very slowly, it returned nearly to its initial length; if cooled rapidly, it required several days to return to its original dimensions. This irregularity makes up most of the 0·5 per cent uncertainty mentioned above.

Plan.—Above 1100° considerable uncertainty has existed in the temperatures of various fixed points. The melting point of nickel, considered as 1484°,* has been frequently employed. The curve of the platinum-rhodium thermoelement, extrapolated beyond the copper-point, has been still more generally used, but like any extrapolation, may lead to quite erroneous results. The only gas thermometer comparison that has been made in this region is that of Holborn and Valentiner,† but by their own estimate the accuracy of the upper portion of their scale is not greater than ± 10°. The chief purpose of our work was, therefore, to establish the temperature of several fixed points between 1100° and 1600° and to find what curve is followed by the platinum-rhodium thermoelement in this region, with an accuracy comparable to that obtained in the lower portion.

The plan of the work is simple. It consists, first, in selecting certain fixed thermometric points, usually melting points of metals, and in determining their reproducibility; second, in making a measurement of the true temperature on the nitrogen scale at or close by one of these fixed points; third, in transferring this known temperature by means of a thermoelement over to the fixed point in question. This transference by the thermoelement is necessary because the thermometer bulb cannot be put directly into melting or solidifying substances at high temperatures. The relation of electromotive force to temperature for any particular kind of thermoelement does not enter into the problem when the temperatures measured are close to the fixed points; a linear correction is then abundantly accurate. The interpolation curve, for any element, between the fixed points established by the gas thermometer, is therefore a separate matter.

The questions which remain to be answered are, then: (1) How exact and uniform can the temperature of the gas in the bulb be made (independently of any effort to measure this temperature)? (2) How accurately can its pressure be measured in order to establish that temperature on the nitrogen scale? (3) How accurately can this temperature be transferred from the thermometer and compared with the fixed melting point? (4) How accurately can the fixed points be reproduced for purposes of calibration of secondary measuring devices?

As has been stated, our experience has convinced us that the most of the variations in the gas scale temperatures of the fixed points commonly in use, as given by various observers, are due, not to differences in the properties of different gases used, nor to differences in pressure, nor to differences between the constant-volume and constant-pressure scales, all of which have been frequently discussed from the theoretical standpoint; but to systematic errors residing in the apparatus and the methods employed. A large portion of the present work has therefore been devoted to finding out experimentally the effect of variations in all those conditions which might affect the results systematically.

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* Holborn and Wien, Wied. Ann., xlvii, 107, 1892; and lvi, 360, 1895.

† Ann. d. Phys. (4), xxii, 1, 1907.

2. *Apparatus.*

In all essential particulars the gas thermometer apparatus is that developed by Day and Clement and already described by them in detail (loc. cit.). It consists of four principal parts: (1) bulb, (2) furnace, (3) furnace jacket, and (4) manometer.

(1) *The Bulb.*—A great deal depends upon the material of which the bulb is made. Primarily and obviously, the bulb must be able to hold the expanding gas without absorbing or losing any portion of it throughout the temperature range of the measurements.

A secondary requirement, the importance of which increases rapidly when high accuracy is sought, is that it shall be possible to use several thermoelements in the furnace with the bulb without their readings being endangered by contamination from the bulb material. As long as this intermediary role of the thermoelement remains a necessary one and alloys of platinum continue to provide the only successful bulb material, the contamination* of the platinum wire of the element by the alloyed iridium or other platinum metal in the bulb will remain a serious consideration in all temperature measurement above 900°.

Although the platin-iridium bulb served well as a gas container, the contaminating effect of the iridium upon the thermoelements made the life of the latter, for measurements of such extreme accuracy, very short. Accordingly, at the close of the first series of experiments, a change was made from the platin-iridium bulb to one of platin-rhodium (80 parts platinum, 20 parts rhodium) 160^{mm} long and 47^{mm} in diameter. Inasmuch as one of the wires of the thermoelement itself contains 10 per cent of rhodium to which the platinum wire is always exposed (and which gradually contaminates it, too, although very slowly), it was thought that the substitution of a rhodium alloy in the bulb might serve to retain the necessary qualities of stiffness and regularity of expansion with a minimum of disadvantage in the matter of contamination. These expectations have been completely realized. Although the rhodium alloy is less rigid at temperatures of 1000° and beyond than the iridium alloy, and requires more careful adjustment for equal pressure within and without, no sagging of the bulb walls or deformation from the gas pressure has appeared up to 1550°. Meanwhile, the contamination of the thermoelements in the presence of the rhodium alloy is now reduced in magnitude about 80 per cent for a given temperature and time of exposure.

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*For a detailed account of the behavior and treatment of contaminated thermoelements, see Walter P. White, Phys. Rev., xxiii, 449, 1906.

(2) *The Furnace.*—The common practice of recent observers (Callendar, Harker, Holborn and Day, Jacquerod and Perrot, Day and Clement) has been to use a cylindrical bulb in which the length was three or four times the diameter, enclosed in a concentric furnace tube (air bath) heated by the electrical resistance of a coil of wire wound upon or within it. To this bulb the heat is applied radially over its cylindrical surface, but no heat is supplied at the ends. The furnace tube itself and the winding of the coils have been changed at different times and in a variety of ways in order to vary the distribution of the heat supply. The arrangement used in most of our experiments consisted of one main coil of platinum wire $1{\cdot}2^{\text{mm}}$ in diameter, wound on the inside of a refractory magnesia tube 36^{cm} long and 2^{cm} thick. As has been our habit for some years, the windings near the ends of the coil are somewhat closer together than those at the middle, but this device is not of itself sufficient* to compensate for differences of temperature along the bulb at all temperatures. In a particular case a favorable arrangement will provide an almost perfect temperature distribution at 500°, but will overcompensate the ends at 1000° sufficiently to spoil the measurements. The conductivity of the bulb metal is wholly inadequate to help out this overcompensation by conveying surplus heat from the ends to the middle of the bulb. On the other hand, a change in the winding which will correct the overcompensation at 1000° provides insufficient compensation at 500°. The arrangement which has become usual with us is therefore to wind the coil somewhat more closely at the ends than in the middle, with the idea of providing partial compensation for the inevitable heat losses at the ends of the furnace in this way, and in addition, to insert supplementary coils of smaller wire in the ends of the furnace tube in order to provide a small, independently regulated heat supply which can be superposed upon that of the main coil and give the desired uniformity at any temperature likely to be employed. A furnace tube arranged in this way, except for accidental variations, caused, for example, by the flaking off of the fur-

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* Day and Clement, loc. cit., p. 411.

nace lining, affords uniform temperature distribution over a length of 20^{cm} in the center of the tube for a range of temperature from 300° to 1550°, and no one temperature is more difficult to regulate than another. This arrangement contains a limitation, however, of considerably greater magnitude than was at first suspected. The ends of the bulb face the comparatively cold ends of the furnace tube and radiate a sufficient quantity of heat toward these cold ends to reduce the temperature of the end surfaces of the bulb some 6 or 8° below the mean temperature of the cylindrical surface.

In so far as this may appear to be a rather obvious condition to be overlooked, it may be remarked parenthetically that it is a common practice of physicists to assume that the temperature is constant over a radial cross-section near the center of a cylindrical furnace which is reasonably long in comparison with its diameter. With this in mind, the probability is even greater that a metallic conductor only 4^{cm} in diameter (the end surface of the bulb) perpendicular to the axis in such a furnace will have a uniform temperature between its center and periphery. The fact is that neither of these assumptions is justified, even in furnaces as long as twenty times the diameter. This was shown in a number of actual measurements made under varied conditions, differences of several tenths of a degree being found as low as 300°, and of several degrees at 1000° and higher.

This situation demonstrates the futility of depending upon metallic conductivity (of platinum) to equalize a steep temperature gradient, and again emphasizes the fact, if further emphasis is necessary, that the air bath, or, more explicitly, the temperature distribution within the heating chamber, is the most uncertain factor remaining in gas thermometry.

On account of difficulties in manipulation and accidental leakage into the thermoelement system, we preferred not to introduce additional heating coils into the furnace tube, and accordingly undertook to stop the loss of heat by inserting thin, platinum-covered diaframs opposite the ends of the bulb. The situation was still further safeguarded, in exchanging the platin-iridium for the platin-rhodium bulb by adding a reentrant tube at the lower end of the bulb, to enable us to measure the actual temperature prevailing at its center as well as over the surface. In this way, we thought to obtain a more representative integral of the surface temperature and a competent comparison of this integral with the temperature actually prevailing at the center of the bulb.

(3) *The Furnace Jacket.*—The furnace jacket was water-cooled and could be closed air-tight around the furnace and bulb together, so that the pressure could be maintained the same within and without the bulb to avoid deformation.

(4) *The Manometer.*—The bulb communicated, by a capillary tube leading out through the furnace jacket, with the manometer, which consisted of two glass tubes communicating through a steel reservoir. At the top of the shorter arm, where the capillary joined it, was a fixed reference point to which the mercury was brought for each measurement of the pressure. A detailed description of the manometer will be found in the previous paper.*

3. *Details, Errors and Corrections.*

The gas thermometer for high temperatures has now reached a stage of development where it becomes necessary to examine many small sources of error. These will be discussed in the succeeding paragraphs without attempting to classify separately the variable errors of observation, and the systematic errors which may arise from conditions of the measurements or from constant corrections.

To bring out the plan of investigation of these errors, it will be well to recall the derivation of the gas thermometer formula. The gas scale, as is well known, is defined by the relation

$$\frac{pv}{1 + at} = \mathrm{K} \qquad (1)$$

in which K and a are constants and t is a function of p and v, the pressure and volume of a fixed mass of the gas. K and a are determined by two further conventions:

When $p=p_0$ and $v=v_0$ (at melting point of ice), $t=0$ (2)
When $p=p_{100}$ and $v=v_{100}$ (at boiling point of water), $t=100$ (3)

It is then evident that

$$a = \frac{p_{100}\frac{v_{100}}{v_0} - p_0}{100\,p_0}$$

which defines a as the mean pressure coefficient of the gas between 0° and 100° (when v_{100} and v_0 are nearly equal); and

$$\mathrm{K} = p_0 v_0 .$$

The temperature, t, is therefore defined by the formula:

$$t = \frac{p\frac{v}{v_0} - p_0}{a\,p_0} \qquad (4)$$

the scale depending upon the gas chosen, the value of p_0, and the ratio $\frac{v}{v_0}$. In the theoretical constant-volume thermometer, this ratio $\frac{v}{v_0}$ is unity, but in the experimental constant-volume thermometer it always varies considerably from 1. We have preferred therefore to treat equation (4) as the fundamental equation, introducing in place of $\frac{v}{v_0}$, however, the proper function of the expansion coefficient of the bulb material.

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* Loc. cit., p. 415, and this article, p. 107.

Since apparatus designed for high-temperature work is not suited for the most accurate determination of a, a has been treated in this discussion as a separately determined constant.

In the experimental gas thermometer, there is always a small space in the tube connecting with the manometer which is at various temperatures other than t. The pressure (p' or p_0') actually measured is not therefore the p or p_0 of the formula. Imagine that this supplementary space is heated up to the uniform temperature t, without any change in its volume, and let the resulting corrected pressure be p (or p_0 as the case may be). Furthermore, let

V = volume of bulb at $t°$.
V_0 = " " " 0°.
v_1 = " " unheated space" which is at temperatures other than t (or than 0°).
t_1 = temperature of this space.
β = linear expansion coefficient of the bulb material.

Under these conditions, formula (4) becomes:

$$t = \frac{1}{p_0 a}\left[p\frac{V+v_1}{V_0+v_1} - p_0\right]$$
$$= \frac{1}{p_0 a}\left[p\left(1+\frac{3\beta t}{1+\frac{v_1}{V_0}}\right) - p_0\right]^{*} \qquad (5)$$

In this formula $\frac{v_1}{V_0}$ is a very small correction term; while the important quantities to be measured are p_0, p, a and β. The ratio $\frac{v_1}{V_0}$ becomes of importance, however, in determining the corrected pressure p from the measured pressure p'. The derivation of this correction is as follows:

The mass of the gas in the unheated volume under the actual conditions of measurement is proportional to $\frac{p'v_1}{1+at_1}$;

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* $$\frac{V+v_1}{V_0+v_1} = \frac{\frac{V}{V_0}+\frac{v_1}{V_0}}{1+\frac{v_1}{V_0}} = \frac{1+3\beta t+\frac{v_1}{V_0}}{1+\frac{v_1}{V_0}} = 1+\frac{3\beta t}{1+\frac{v_1}{V_0}}$$

the mass of the gas within the bulb is proportional to $\frac{p'V}{1+at}$. If we now suppose the unheated space raised to the uniform temperature t without change of volume, the pressure being thereby raised to p, the total mass is proportional to $\frac{p(V+v_1)}{1+at}$. Therefore,

$$\frac{p'v_1}{1+at_1}+\frac{p'V}{1+at}=\frac{p(V+v_1)}{1+at}$$

whence

$$p-p'=p'\left(\frac{v_1}{V+v_1}\cdot\frac{at-at_1}{1+at_1}\right)$$

This correction is easily calculated and tabulated; or, better, the factor in parenthesis (in the second member of the equation) is plotted against temperature. In practice, the volume v_1 is divided into three portions at temperatures t_1', t_1'', and t_1''' as explained on p. 109, and the corrections obtained from the curve for each of these portions are simply added together to obtain the total correction $p-p'$. With these corrected pressures, p_0 and p, the temperature t is calculated by formula (5) on page 101.

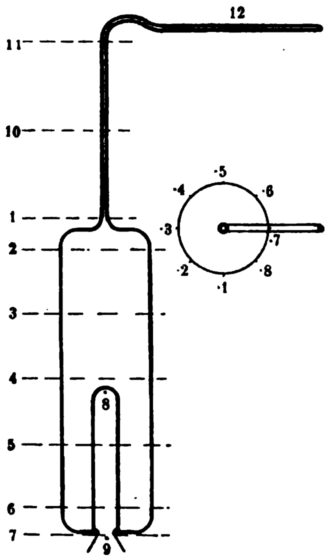
The discussion of errors and corrections will now be taken up under the general outline sketched on page 96.

A. Temperature of the Gas in the Bulb. (a) Uniformity.—Above the temperatures where a liquid or vapor bath can be used to secure uniformity, the differences of temperature between different parts of a furnace has always been a serious limitation to the accuracy of the gas thermometer. This variation, even in a furnace containing well-conducting materials, is much larger than has usually been assumed, and the three equalizing factors of conductivity, radiation, and convection by air-currents, are all credited with much greater influence in bringing about uniformity than they really possess. It sometimes happens that our faith in these factors is inversely proportional to our quantitative information.

To remove this source of uncertainty, Day and Clement introduced two auxiliary heating coils in the furnace, one at each end, and by varying the three independent currents, brought the temperature at the middle and at both ends, on the outside of the bulb, to equality.

In our first measurements with the new bulb, the end elements were placed on the axis of the bulb, in positions 1 and 9 (fig. 1), instead of on the outside surface. It became evident at once that the supporting tube in the bottom of the furnace, used in the work of Day and Clement, had a considerable cooling influence on the central portion of the bottom, an effect which would tend to make their results low. This effect was largely obviated by using, in place of the heavy magnesite tube, a thin Marquardt porcelain tube in the top of which was placed a Marquardt crucible, cut out into a three-pronged support. The bottom of the crucible acted as a screen to prevent radiation from the bottom of the bulb, and the smaller thickness and thermal conductivity of the tube practically prevented the loss of heat from the bottom by conduction. Later, a second diafram was added, about 1^{cm} lower down, primarily for the purpose of centering the tube and bulb in the furnace, but without noticeable effect on the temperature distribution.

FIG. 1.



SECTION.

FIG. 1*a*.

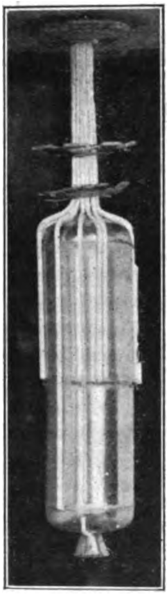


FIG. 1. Numbers indicate the positions of the thermoelements grouped about the bulb.

FIG. 1*a*. A photograph of the bulb made after the palladium-point determination showing all the elements and the diaframs in position.

In addition to the three thermoelements mentioned, a fourth was located inside the reentrant, in position 8.* Several trials under varied conditions confirmed the fact that this element, when the other three were set equal, was 2° to 3° hotter than the one on the outside. A thorough exploration of the distribution of temperature over the surface of the bulb was therefore undertaken.

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* See fig. 1, and note, p. 104.

Since the number of wires which could be led out through the packed joints was limited, the plan was adopted of using the bulb itself as a differential thermoelement, single platinum wires being tied to the bulb at points whose temperature was to be determined. Each of these wires formed, with the platinum of the standard element tied to the bulb at the middle, a differential element which would read zero if the wires were alike and if no difference of temperature existed between the two points on the bulb.

The relation of the wires was established by sealing each in turn to the platinum of the standard, and measuring their E.M.F. at various temperatures. The readings varied, according to the quality of the wire, from 0 to 40 microvolts. The method of evaluating differences of temperature, when such existed, is discussed on page 118.

The distribution of temperature lengthwise of the bulb was first investigated, and auxiliary wires were placed at the levels 1 (base of stem), 2 (top shoulder), 6 (bottom shoulder), 7 (bottom, outside of funnel), in addition to thermoelements at 4 (middle outside), 8 (inside reentrant), and 9 (bottom, just inside of funnel).*

With this system of thermoelements, it was found that at 1082°, when 9 was brought to equality with 4 and 1, the bottom of the bulb was superheated 6 to 8° at position 6, and about 4° at 7, due entirely to the fact that the thermoelement at 9, not being in contact with the bulb, lost sufficient heat by conduction and radiation downward to keep its temperature below that of the metal surrounding it. The element at 8, on the other hand, received heat by conduction up the reentrant tube and by radiation from below, which made it read higher than the element at the same level outside. The element at position 9 was therefore discarded and each setting of temperature made with reference only to the elements which were attached directly to the bulb.

The temperature between the middle and the top shoulder was also examined in several experiments. The temperature at this position was found to be within 0·5° of the other two, with a tendency to be lower than these.

Further experiments showed that in addition to the possibility of vertical variation of temperature, there was a variation around the circumference of the bulb. This amounted in the worst case (at 1450°) to a variation of 1·3° from the mean, four elements being used around the circumference to make the test. This variation seemed to be due either to unequal conductivity of the furnace material at different points or to the falling off of small portions of the furnace lining, leaving exposed places on the wire. Variations of this character are probably an unavoidable result of using a furnace where the heat supply is so near to the point where it is measured, as is the case with the furnace which is wound on the inside. This form of winding is necessary, however, in order to reach the highest temperatures, so that absolute uniformity of temperature around the bulb had to be sacrificed to increased range of the instrument.

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* The system of numbering the positions of elements on the bulb is shown in fig. 1. The figure before the decimal point indicates the horizontal level, the figure after the decimal indicates the orientation around the bulb. For instance, an element in position 3·5 would be about half way between the top and middle and on the side of the bulb away from the front of the apparatus.

Fig. 2.

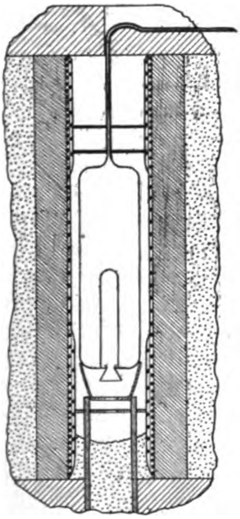

Fig. 3.

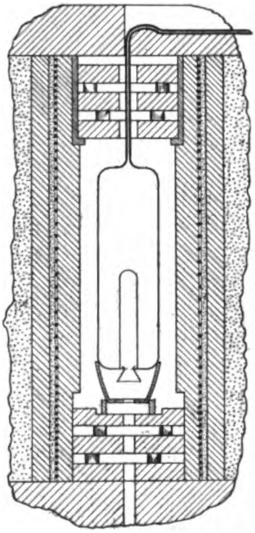

Fig. 2. Section of furnace and bulb showing the arrangement of coils and diaframs about the bulb which gave the most uniform temperature distribution in the measurement of both high and low temperatures. The supplementary end coils were independently heated and regulated.

Fig. 3. A special arrangement of the heating coil and diaframs designed to give a very uniform temperature distribution about the bulb. The coil was heavily ballasted inward with a good heat conductor and outward with a poor conductor. The heating coil was also divided into three sections which could be independently regulated. This furnace was used at the copper point only.

After this variation was discovered, measurements were always made with four elements at equal distances around the circumference of the bulb and the mean of their readings was taken.

In order to be perfectly certain that no systematic error was being introduced by using this one form of furnace (fig. 2.) throughout, it was replaced temporarily by a furnace of platinum wire wound on the *outside* of a similar tube. In this way a heavy mass of good heat-conducting material was introduced between the source of heat and the bulb, with the expectation that a more uniform temperature might thereby be obtained in the inside space. The two types of furnace are shown in figs. 2 and 3.

A measurement at the copper point with the outside-wound furnace gave as the melting point of copper 1082·6°, which differs only 0·4° from 1082·2°, the mean of the results obtained at the same pressure with the other furnace, and is identical with the final mean of all the results, thus proving that no systematic error was to be feared from the inside-wound type of furnace. The horizontal uniformity obtained in the outside-wound furnace was better than that in the inside-wound, but the furnace was more difficult to regulate and to hold at a given temperature.

(*b*) *Constancy of Conditions.*—Several causes interfered with the establishment of a constant temperature for observation. The three heating currents required constant observation and readjustment with the gradual extension of the heated zone toward the outside of the furnace. This comes to equilibrium for a particular temperature after about half an hour, after which the bulb was held steady 15–30 minutes longer before readings of the pressure were taken. The temperature thus established could be relied upon to remain constant to within 1 to 3 microvolts (0·1° to 0·3°) during the course of the pressure measurements.

Above 1100° a noticeable leakage of current from the heating coil into the bulb and thermoelements frequently appeared. This may have been due in part to conductivity across the narrow air space between bulb and coil, but was probably chiefly due to accidental contact between the protecting tube of one of the thermoelements and the furnace wall. To obviate any uncertainty from this cause, it was found necessary to use alternating current for all temperatures above 1100°. This was less easy to regulate than the direct current from storage batteries, but by careful regulation of the voltage of the motor generator supplying the alternating current, equally satisfactory results were obtained.

The constancy and exactness of the temperature at 0° were beyond question. On several occasions pressure measurements at 0° were made at intervals of one-half to one hour and no measurable difference found. Similarly, repacking the bulb in a fresh supply of ice gave exactly the same value.

B. Definition of Temperature by Measurements of Pressure.—The procedure in measuring the pressure, p', was as follows: First the three mercury thermometers on the manometer were read to determine the temperature of the mercury column and scale; then three to four settings of the barometer were made, alternating with measurements of the manometer. The mercury thermometers were read again at the close. During this interval the other observer made as many readings as possible of all the thermoelements.

Before the manometer was connected to the bulb, the point on the scale corresponding to the reference point of the manometer* was determined once for all before the manometer was connected to the bulb, by connecting the two arms and raising the mercury to the point, as in a regular pressure measurement. Subsequent manometer readings were subtracted from this fixed level, and the resulting difference corrected for the temperature and calibration corrections of the scale and then reduced to 0°. The barometer reading was similarly corrected. The algebraic sum of the two gave the pressure p', in terms of a centimeter of mercury at 0° and at the latitude and elevation of the laboratory. Since the absolute value of the pressure does not enter into the gas thermometer formula, corrections for altitude and latitude are superfluous.

Errors and Corrections in p'.—The level of the fixed reference point of the manometer varies with the temperature of the room because of the difference in expansion of the brass scale on the one hand and of the glass tube of the manometer which carries the fixed point on the other. This correction can be calculated from the expansion coefficients of the materials and amounts to $0{\cdot}04^{\text{mm}}$ per 5°. Its direction and amount were checked experimentally by determining the fixed point at two temperatures differing by about 10°, the room being open on a cold day for the one case, and then closed and heated for the other. The difference found was $0{\cdot}09^{\text{mm}}$, and that calculated $0{\cdot}08^{\text{mm}}$.

The lengths of the divisions of the brass scale were corrected for change of temperature by a formula determined for this scale at the Normal-Aichungs-Kommission, the absolute length of the scale having been determined at 16°. In addition, calibration corrections, determined for each millimeter of the scale, were applied. The total scale correction was always less than $0{\cdot}15^{\text{mm}}$, hence the temperature measurement by the adjacent mercury thermometers was abundantly accurate for this purpose.

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* p. 100.

The length of the mercury column was reduced to 0° by the expansion coefficient given in the Landolt-Börnstein-Meyerhoffer Tabellen. This correction varied from 0 to about 3·00^{mm}. As the mercury thermometers were calibrated and read to 0·1°, the uncertainty in this correction due to uncertainty in the room temperature may amount to 0·05^{mm}. For the calibration the mercury thermometers were compared with a Richter standard thermometer calibrated at the Reichsanstalt.

The barometer reading was corrected to 0° by the Landolt-Börnstein-Meyerhoffer table for barometer with brass scale. Two Fuess barometers were used. Both had been tested by the Bureau of Standards; one had an absolute correction of 0·06^{mm}, the other was exact. This was checked by direct comparison of the two. The variable error in the barometer is probably about the same as in the manometer reading (0·05^{mm}). On a very windy day or during the approach of a storm, the barometer was too unsteady to permit satisfactory measurements to be made.

A further small correction to the barometer was necessary to allow for the weight of the air column between the cup of the barometer and the top of the mercury in the open manometer column. This correction was appreciable, amounting to 0·16^{mm} in the extreme case.

To give some idea of the effect of these small corrections upon the final temperature measurement, it may be added that 1·00^{mm} corresponds approximately to 1°.

To determine the corrected pressure, p, from the measured pressure, p' (see page 101), the volume of the unheated space, v_1, connecting the bulb with the manometer, must be known.*

TABLE I.— *Unheated Space.*

Space	Volume, c.c.		Uncertainty		Max. effect at Cu. pt. of errors
	Before Apr. '09	After Apr. '09	of vol.	of temp.	
Pt-Rh capillary, bulb to top furnace (v_1')	0·055	0·055	0·002	100°	0·04°
Pt-Rh capillary, top to outside furnace (v_1'')	0·086	0·086	0·003	50°	0·20°
Pt-Rh capillary to gold capillary v_1'''	0·102	0·054	0·015	0·5°	0·20°
Gold capillary	0·094	0·066			
Pt capillary and Ni valve	0·025	0·025			
Space above meniscus	0·023	0·023			
Total	0·385	0·309			0·45°

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*See discussion of this correction, Day and Clement, loc. cit., p. 410.

This was calculated from the dimensions of the capillary. The figures are given in Table I. This volume was reduced in April, 1909, by bringing the manometer closer to the furnace, since the water jacket of the furnace cut off the heat so completely that there was no risk in bringing the manometer as close as possible (35^{cm}). The volume v_1 was thereby reduced from $0·39^{cc}$ to $0·31^{cc}$, and the ratio $\frac{v_1}{V_0}$ from 0·00187 to 0·00150.

The volume, V, which enters into the correction term (see page 102) was determined by weighing the bulb empty, and filled with distilled water at a known temperature. A very accurate determination of this volume was not necessary, the important requirement being that the volume should not change during a run. A check on change of volume was obtained in the measurement of the value of p_0. The volume of the bulb at 0°, up to the base of the capillary stem, was found to be:

On 13 June, 1908 (new) . ... $205·74^{cc}$
On 18 " . " (after 1450°) . . . . . $205·75^{cc}$
On 20 Apr., 1909 .... $205·82^{cc}$

The volume of the unheated space, v_1, was arbitrarily divided into three portions for the convenient determination of its average temperature, t_1. The first portion, v_1', extended from the base of the stem to the top of the upper brick of the furnace (see fig. 2); the second portion, v_1'', included the capillary stem as far as the outside of the furnace; the third portion, v_1''', extended to the surface of the mercury in the manometer and included all of that portion of the unheated space which remained at room temperature.

The temperatures of the portions v_1' and v_1'' were determined by placing a thermoelement at different points along the stem during several of the runs. As this temperature does not need to be known accurately, a few measurements gave a sufficient indication of the distribution of temperature in the portion of the "unheated space" within the furnace.

A liberal estimate of the degree of uncertainty in the values of v_1 and t_1 has been made and is included in Table I, together with the effect which such errors would have on the calculated temperature, t, at the copper point.

Errors and Corrections in p_0'.—The same instrumental corrections apply to p_0' as to p', but their proportional magnitude is, of course, larger. The values of the uncertainty in t due to these small errors will be found in Table IV.

Changes in the value of p_0 (the ice point) after heating to high temperatures have always been disturbing factors in gas thermometer measurements and have introduced uncertainties of a very intangible kind. This was especially true of the porcelain bulbs formerly used, where both changes of volume and emission or absorption of gases by the walls occurred. The restoration of the platinum metals to favor as materials for the gas thermometer bulb has practically eliminated this uncertainty. During the present work small changes in the value of p_0 have frequently occurred after heating to a high temperature, which seem not to be due to any change in volume, for the determinations of the volume, V_0, given above (p. 109), show a total change after a year's work corresponding to less than $0{\cdot}1^{mm}$ in p_0. In the early part of the work, the passage through the bulb wall of hydrogen or some other gas produced by the reducing action of wood fiber in an asbestos board insulator within the furnace, was suspected as being the cause of irregularity, particularly in view of the fact that Holborn and Valentiner had difficulties from this cause. Further, it was several times observed that heating the furnace and bulb to a higher temperature than they had reached before, caused a slight increase in the value of p_0,—whether due to some gas passing in from the outside, or coming out of the wall of the bulb, is not known. Air dried over calcium chloride was used outside of the bulb in the furnace enclosure throughout the work, and no indication was ever obtained of the passage of either oxygen or nitrogen through the wall of the bulb, since measurements at a given temperature (after the first heating to that temperature) gave the same value of p_0 within the error of measurement.

On one occasion an almost inappreciable leak in the manometer connection caused some uncertainty. All measurements affected by this error, when it was discovered, were rejected.

a.—Since the gas thermometer apparatus as arranged for high temperature measurements is not suited to a determination of the value of a (the pressure coefficient of the gas from 0 to 100°) with an accuracy comparable to that attained by Chappuis,* the value of a was treated as a constant. The figures used were:

$$\text{For } p_0 = 345 - 347^{mm},\ a = 3665{\cdot}8 \times 10^{-6}$$
$$\text{For } p_0 = 217 - 221^{mm},\ a = 3664{\cdot}0 \times 10^{-6}$$

A number of independent determinations of a for different pressures were made by Day and Clement† with the platin-iridium bulb, but they show no appreciable difference from those by Chappuis within the experimental error of the apparatus. The probable error in Chappuis' results is not great enough to affect the high temperature values.

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* Trav. Mem. Bur. Int., vi and xii, 1888 and 1902.

† Day and Clement, loc. cit., p. 442.

Pure nitrogen was used throughout as the thermometric gas.* The storage tank was refilled several times so that not all the gas was from the same original supply; the filling of the bulb was also changed several times. The bulb was first completely evacuated and heated to a high temperature, after which the connections and bulb were rinsed out several times with the purified gas before the final filling.

Expansion Coefficient of the Bulb. (β).—The substitution of a new alloy in place of the platin-iridium made necessary a new determination of the expansion coefficient of the bulb material. The method of its determination and the comparator used for the purpose were fully described in the earlier article† and do not require to be repeated here.

Three additional precautions were taken in carrying out the measurements: The bar was increased in length to 0·5 meter, and in diameter to 6^{mm}, in order to increase the sensitiveness of the determination and the uniformity of temperature along the bar respectively. In this case the bar was also made at the same time and from the same alloy as the bulb itself, and was therefore identical with it in composition.‡

In ruling the bar, the lines were spaced $0{\cdot}2^{mm}$ apart instead of $0{\cdot}5^{mm}$, as in the previous investigation. This enabled a greater number of observations to be made within a narrow region than heretofore, and has thus made it possible for us to avoid the error from parallax described in the previous paper.§

The third precaution involved a slight change in the comparator itself, and was made at the suggestion of Chappuis. Our custom had been to verify the distance between the fixed hairs of the microscopes before and after each heating by measuring this distance in terms of a standard brass bar calibrated at the Bureau of Standards. The brass bar was then replaced by the platin-iridium bar before the heating began, and the length of the latter was measured in terms of the initial distance between the fixed hairs, at intervals of 50° or

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* It was prepared by dropping a solution of 200 grams of sodium nitrite dissolved in 250 grams of water, into a warm solution containing 350 grams of ammonium sulphate and 200 of potassium chromate in 600 of water. It was passed through a mixture of potassium bichromate and sulphuric acid and stored over water. For use in the gas thermometer it was purified by passing through calcium chloride, hot copper gauze, potassium bichromate in sulphuric acid, 2 bottles potassium pyrogallate solution, sulphuric acid, calcium chloride and phosphorous pentoxide.

† Day and Clement, loc. cit., p. 425.

‡ The new bulb, as well as the bar, were made with the utmost care by Dr. Heraeus, of Hanau, Germany, for this investigation. We have had repeated occasion in the past to make public expression of our indebtedness to Dr. Heraeus for his interest and assistance in this work, and it is a pleasure to repeat this acknowledgment here.

§ Day and Clement, loc. cit., p. 435.

100° up to 1000°. This mode of procedure involved the assumption that the agreement of the measurements made before and after heating afforded adequate proof that no change had taken place *during* heating. The justification for this assumption lay in the fact that, (1) the furnace was completely water-jacketed to prevent any heat reaching the microscopes from the furnace; (2) suitable insulating material introduced between the observer and the microscopes cut off any disturbing influence from the near approach of the observer's body; (3) the microscopes themselves, and the carriages upon which they were mounted, were connected by carefully selected invar bars of negligible expansion coefficient, and, finally, (4) the faithful agreement of all the measurements before and after the many heatings left no reason for suspecting a variation.

FIG. 4.

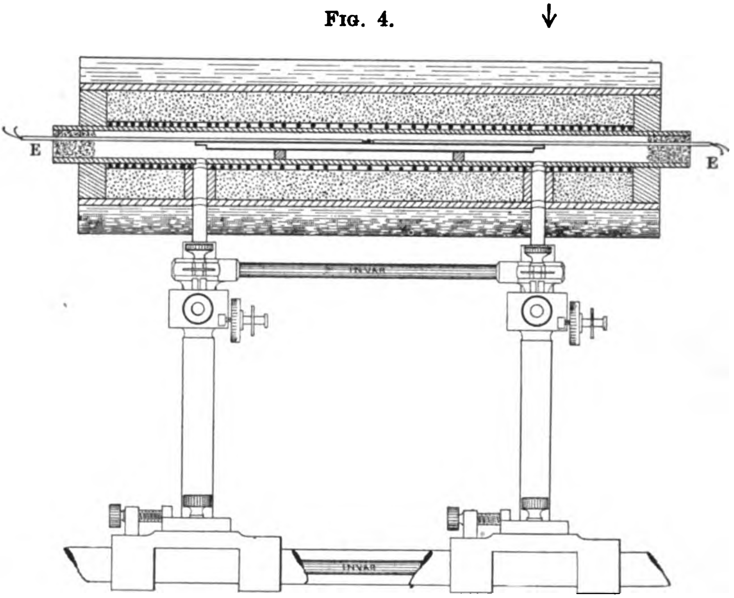

FIG. 4. Section through furnace showing bar, thermoelements (E, E) and microscopes in position. A section through the arrow is shown in fig. 5.

Notwithstanding these conditions, it appeared to Chappuis that some positive proof should be offered that the distance between the cross-hairs remained unchanged while the heating was going on, inasmuch as all the measurements were made in terms of this distance. Accordingly, at his suggestion, it was arranged to retain a standard unheated bar in the field of the microscopes throughout the readings, so that the distance between the cross-hairs would be subject to check at any time during the observations. The arrangement made for the purpose is very simple and effective, as can be seen from the neighboring diagrams (figs. 4 and 5). The last two series of measurements were made with this appliance, and the fixed distance was found to remain constant throughout the series to within $0{\cdot}003^{\mathrm{mm}}$, although on first setting up the apparatus a gradual adjustment of strain, amounting to $0{\cdot}012^{\mathrm{mm}}$, took place during the first two days.

The determination of β is subject to two errors; the first is uncertainty of temperature, the second occurs in the measurement of the change in length.

Fig. 5.

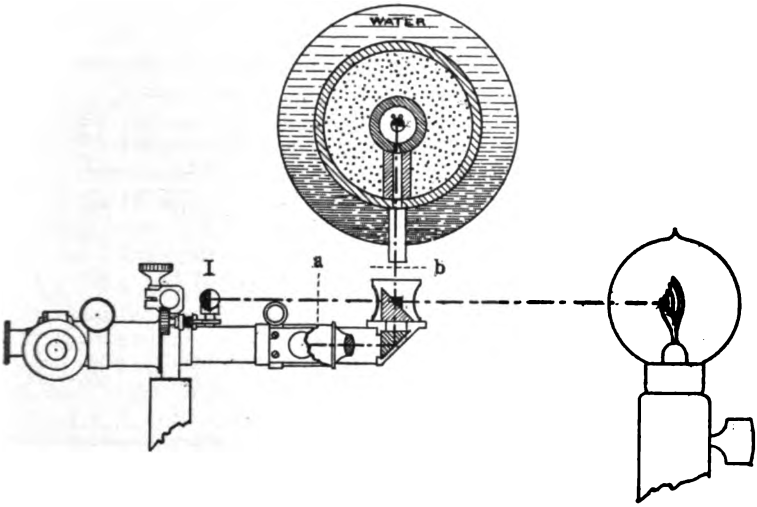

Fig. 5. A section through the furnace at one of the openings, showing the method of illumination of the heated bar and the standard cold bar (I) together with an arrangement for checking the distance apart of the cross hairs at each temperature. With a screen inserted at *a* only the hot bar is visible; with the screen at *b* only the cold bar.

It was impossible to wind the furnace (70^{cm} long and 2^{cm} inside diameter, with two side openings) so as to give a perfectly uniform temperature along the bar; but as the furnace winding and consequent distribution of temperature were varied considerably for each run, the uncertainty from this cause was eliminated in the average of all the observations. The error in the temperature measurement itself was probably not over 2°, which would give an error of less than 0·2 per cent at the highest temperature. Two thermoelements with a common junction were used, one entering from each end of the furnace. This not only gave a second temperature reading in confirmation of the first, but a positive check upon the appearance of contamination in the thermoelements.*

With a half meter bar and a temperature interval extending from zero to 1400°, the total expansion amounts to about 7·8$^{\text{mm}}$. The micrometers reading the expansion were read with an accuracy of 0·002$^{\text{mm}}$.

There was some indication of a very small hysteresis in the expansion and contraction. Although the amount was not much greater than the experimental error, the measurements indicate that the bar was slightly shorter after heating than before, and that it gradually regained its original length.

The measurements at room temperature are given in Table II. The five measurements in this table which were made within a few hours after the bar had cooled from a high temperature, excluding the two where the bar was bent, average 500·095; while the ten measurements (excluding the first) which were made two days or more after heating, average 500·106. The difference is only 0·002 per cent of the total length, or 0·12 per cent of the total expansion to 1500°, or about 0·7 per cent of the expansion to 300°. This effect is, therefore, probably responsible for the observed irregularities between 0° and 300°, at which temperature most of the measurements were begun.†

TABLE II.—*Length of Platinum-Rhodium Bar.*

Date	Max. preceding temperature	Length at 0°	Date	Max. preceding temperature.	Length at 0°
1 July 1908	(New)	500·068	26 Sept. 1908	1150°	500·094
6 " "	900°	500·110*	1 Oct. "	25°	500·119
9 " "	28°	500·105	6 " "	1300°	500·034†
13 " "	900°	500·098*	27 " "	900°	500·108*
17 Sept. "	900°	500·108*	30 " "	1400°	500·096
19 " "	1200°	500·090	6 " 1909	28°	500·103
20 " "	23°	500·105	12 " "	22°	500·108*
22 " "	1200°	500·087	13 " "	1000°	500·109
24 " "	24°	500·096	15 " "	1400°	500·074†

* After interval of 4–7 days.

† Bent, after heating beyond last temperature at which measurements were made.

C. Transference of Temperature by the Thermoelement.—The electromotive forces of the elements attached to the bulb were measured by a Wolff potentiometer. The standard of electromotive force used was the true volt, in terms of which the E.M.F. of the Clark cell is 1·4328 at 15°, and of the saturated cadmium cell used, 1·01918 volts at 25°.

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* Day and Clement, loc. cit., p. 419.

† Kammerlingh-Onnes (Konink. Ak. Wet. Amsterdam, Proc., x, 342, 1907) has found the same effect after cooling platinum to very low temperatures.

Several small corrections are necessary in order to obtain the true E.M.F. of the thermoelement. The calibration corrections of the potentiometer (Reichsanstalt calibration) were all negligible except that for the fixed resistance to which the standard cell was attached. This correction amounted to 1·3 microvolts in 10,000. The correction for the change of resistance with temperature of the potentiometer was also negligible. The E.M.F. of the standard cell varies with the temperature; hence the temperature of the cell was read at each measurement and a small correction applied. The readings were correct at 21·5°. For a variation of 5° from this temperature the correction was 2·2 microvolts in 10,000 microvolts. The resistance of the contacts of the potentiometer, and the small E.M.F.'s existing at contact points in the circuit of the thermoelement, introduced another small error which was determined by placing the thermoelement in ice and reading the E.M.F. This correction varied for the different elements from −1 to +4 microvolts.

As a check upon the absolute value, a Weston standard cadmium cell (calibration by the Bureau of Standards) whose E.M.F. was read directly on the potentiometer, was compared with the saturated cell each day. The agreement of the corrected values was usually within 0·5 microvolt. As in the case of the pressure measurement, the absolute value of the E.M.F. is not of importance, since it is used only for transference from the fixed points to the gas thermometer; the above corrections were applied, however, to reduce the readings to a common standard.

The effect of contamination of the thermoelement wires in furnace readings was much greater than the above mentioned errors.* Up to 1100° the contamination was not serious, but above that temperature the wires take up iridium together with some rhodium. It was hoped that the replacement of iridium in the bulb by rhodium, which is very much less volatile, would do away with this error, but there appeared still to be a very small percentage of iridium in the furnace wire, enough to affect the thermoelement wires appreciably, even though this furnace wire had been especially purified for this purpose.

Although the task became much longer and more laborious, it was thought wise to make an effort to avoid the error from contamination, even of this diminished magnitude, rather than to attempt to compromise with it by any scheme of approximate evaluation. Accordingly, after every exposure of sufficient length to endanger the thermoelectric readings, all the thermoelements were removed from the furnace and their wires tested for homogeneity. Where contamination was found, the contaminated portion of the wire was at once cut off This is the only absolutely safe method of avoiding errors from this cause, for it amounts to the use of new thermoelements exclusively in all the determinations of temperature distribution within the furnace as well as for establishing the absolute temperature of the metal melting points.

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* For a more thorough discussion of this effect, see Day and Clement, loc. cit., p. 419; and W. P. White, Phys. Rev., xxiii, 449, 1906.

A very simple method of testing the wires for contamination has been developed which consists in connecting the junction end of the wire to be tested, together with an uncontaminated wire, to the potentiometer and moving the free end of the standard wire along the wire to be tested, while heating the contact point of the two with a blast lamp.* The variation of the E.M.F. produced at this junction indicates the degree of contamination of the wire; in the uncontaminated portion this E.M.F. is small and constant within 3 mv. The temperature obtained by the blast lamp flame is sufficiently constant for the purpose and lies between 1460° and 1500°.

The wires could be relied upon to give a constant E.M.F. within 2 mv. at 1000° over a length of at least 50^{cm}, so that redeterminations of the fixed points were not necessary after cutting off each small portion of contaminated wire. Each test for contamination was continued over the 50^{cm} of wire adjacent to the hot junction and so served as a test for the homogeneity of the new wire which replaced the portion cut off. In two cases a sudden change of E.M.F. along the unused wire amounting to about 10 mv. showed the probable presence of a junction point in the original sample from which the wire was drawn. Such a junction point was of course not introduced into the heated portion of the furnace.

In this connection, it should be pointed out that the relative weight to be given to the element inside the bulb, as compared with the outside elements, is greater at temperatures above 1100° than at temperatures below, for two reasons: (1) The temperature at the middle of the bulb is not so much influenced above 1100° by the temperature of the lower part of the furnace, as it is below 1100°; (2) the outside elements are much more subject to contamination than the inside element by reason of the protection afforded by the intervening bulb walls against contaminating material from the heating coils. This is well shown by the data in Table VIII on the melting points of diopside, nickel and cobalt. In the first measurements of these temperatures, the elements were left on the bulb through several runs, in consequence of which the temperatures derived by the outside elements steadily increase through the series (i.e., the readings of the outside elements on the bulb steadily decreased), whereas the temperatures derived from the inside element are fairly constant. Its contamination was found to be less in amount and distributed over a region of more constant temperature.

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* W. P. White, loc. cit.

For insulating the thermoelement wires from the bulb and furnace, capillary tubes, both of Marquardt porcelain and of silica glass, were employed. The Marquardt tubes are open to the objection that they are very porous and offer little protection against contamination. The silica glass capillaries protected the wires very much better, but at 1100° and above they devitrified rapidly and at the end of a measurement at 1400° or over fell from the wires in small fragments, so that the wires had to be taken off and reinsulated after a single run.

For the convenience of others who may confront similar problems, it may be added that such extreme precautions as cutting off the elements at the first sign of contamination are excessive for most purposes. The region of highest temperature, and therefore of most rapid contamination in a good furnace, is also a region of constant temperature. Contamination would therefore produce little effect upon the reading of the thermoelement until it had crept out into the colder parts of the furnace, which it will do slowly during long exposures. The distribution of the contamination in an aggravated case is shown in the accompanying table, which is arranged in such a way that not only the magnitude of the contamination but also its distribution with respect to the bulb is roughly shown. The electromotive forces are determined, as has been explained, by bringing successive points of the contaminated

		Before Heating. Microvolts	After Heating. Microvolts
	40^{cm}	−4	−4
	35	−6	−8
Outside of furnace	30	−8	−7
	25	−9	−6
Bend of stem	20	−6	−10
	15	−5	−3
	12	−5	+2
	10	−5	+9
Shoulder of bulb	8	−5	+83
	6	−5	+83
	4	−6	+41
	2	−6	+55
Middle of bulb	0	−8	----

wire into contact with an uncontaminated one in a blast flame (temperature, 1460–1500°), the cold junction being maintained constant at 0°. The absolute magnitude of the numbers in the column "before heating" represents the electromotive force between two uncontaminated platinum wires of (nominally) equal purity. Its constant value is a measure of the homogeneity of the new wire. Its departure from this constant value "after heating" is a measure of the contamination it has received. Slight irregularities are the result of variations in the blast flame temperature. Such observations merely serve to furnish information about the distribution and approximate amount of contamination received by the element, but do not of themselves provide the data to correct its reading in a particular furnace.

Integration of Temperatures over the Bulb.—By the method which has been already described (p. 104) the differences of temperature between the ends of the bulb and the middle were determined differentially by means of platinum wires attached to the bulb itself. Temperatures about the circumference were measured by separate thermoelements, as it was not practicable to measure these differences differentially because of the necessity of passing a platinum binding wire around the bulb to hold the four elements in position. A check on the accuracy of this differential method was obtained by using in one case a thermoelement at the top shoulder of the bulb and thus measuring the temperature at this point both directly and differentially by means of the platinum wire of this element. The two temperatures agreed within 0·8° when the deviation from the middle was 6°; when the temperatures at the middle and top were nearly equal, the two methods agreed to 0·1°.

Table III contains values of $\frac{\Delta E}{\Delta t}$, the rate of change of E.M.F. with temperature at various temperatures from 400° to 1500°, both for the 10 per cent rhodium alloy and for the 20 per cent

TABLE III.—*Values of* $\frac{\Delta E}{\Delta t}$ *for the alloys 90 Pt. 10 Rh. and 80 Pt. 20 Rh.*

Temp.	90 Pt. 10 Rh.	80 Pt. 20 Rh.
400°	9·4	11·5
600°	10·1	12·8
800°	10·8	14·2
1000°	11·4	15·6
1200°	11·8	16 9
1400°	12·2	17·5
1500°	12·4	17·8

alloy of which the bulb was made. The data for the 20 per cent alloy (which need be only approximate) were obtained by two methods: (1) An element was made up by combining a platinum wire with the 20 per cent rhodium bar used for the expansion coefficient determination, and its readings compared directly with those of a 10 per cent rhodium element in the melting point furnace. (2) A platinum wire was connected from the stem of the gas thermometer bulb outside of the gas thermometer furnace to the ice box, and the E.M.F. determined against the standard platinum wire attached to the middle of the bulb. In both cases, the E.M.F. of the junction of platinum with the rhodium alloy at room temperature was applied as a correction.

In order to obtain the true E.M.F. corresponding to the temperature as measured by the pressure of the gas in the bulb, it is necessary to integrate the various readings over the surface of the bulb. The following arbitrary weights were given to the different positions of elements on the surface:

Top axis	(position 1)	5
Top shoulder	(" 2)	20
Middle	(" 4)	55
Bottom shoulder	(" 6)	15
Bottom axis	(" 7)	5

The elements on the axis at both top and bottom, although sometimes deviating rather widely from the others, have comparatively small weight, as they affect only a small portion of the total volume. The element at the lower shoulder of the bulb is given less weight than that at the top because of the smaller volume of the lower half, due to the presence of the reëntrant tube.

It was easy to show experimentally that it matters very little what these relative weights assigned to the different readings may be, since the total correction was usually small. In a number of cases, two different settings of the temperature distribution were made at each temperature, one in which the elements at the top and bottom shoulders of the bulb were made equal to the middle, and one in which the elements at top and bottom on the axis of the cylinder were made equal to the middle. The pressures corresponding to these two settings, reduced to the same reading of the standard element, are shown for several typical cases in the table below.

Date	Temp.	Pressure when 1, 4, and 7 were equal	Pressure when 2, 4, and 6 were equal
22 Jan. 1909	1082°	1038·82^{mm}	1038·64^{mm}
2 July 1909	1395°	1285·43	1285·17
17 Sept. 1909	1489°	1331·40	1330·63

It is evident that even without any correction for the different distribution in the two cases, the readings agreed within 0·2–0·8^{mm}, or about 0·2–0·9°, so that the variation between any two arbitrary sets of weights which might be given to the different readings must lie well within this limit.

The Transfer to the Fixed Points.—After the thermoelements are removed from the bulb, their E.M.F. at the fixed points must be determined by immersing them in melting or freezing metals or salts. The instrumental corrections to the readings so obtained were the same as in the case of the gas thermometer readings. The error due to contamination was also present above 1100°, just as in the gas thermometer furnace, and was a very disturbing factor in determining the melting points of nickel, cobalt and palladium. Its source, however, was not usually iridium vapor from the furnace or rhodium from the wire of the element, but was either vapor of the melting metal itself, or (when a hydrogen atmosphere was used) the products of reduction of silica. In the presence of hydrogen, silica rapidly deteriorates platinum wire by reduction and alloying, as has been shown in this laboratory by Shepherd,* and elsewhere by several observers. The contamination can be partly prevented by the use of a glazed porcelain tube surrounding the thermoelement, instead of an unglazed magnesia tube; but an additional uncertainty is thereby introduced through the contamination of the melting metal by the melted glaze on the porcelain. For this reason nickel and cobalt did not prove to be as satisfactory fixed points as had been hoped, since it was necessary to melt them in an atmosphere of hydrogen. Palladium, however, can be melted in the open air and serious contamination by silicon thus be avoided, although the palladium itself gradually contaminates the wire.

Above 1100° it is better to make direct comparisons of all the elements with one or two whose fixed points have been determined, rather than to contaminate them all by a direct determination. For making these comparisons, the plan first used was to bring a crucible of molten silver to a constant temperature and insert the elements (protected by a glazed Marquardt porcelain tube) successively into the silver bath. There is an uncertainty, however, in these measurements of 2 to 3 mv., caused by small differences of temperature within the tube and to the slight cooling produced by introducing cold wires into the furnace. A better method is to join together the two platinum wires and the two alloy wires of the elements to be compared, and determine the small E.M.F.'s of each pair at several temperatures, from which the difference between the elements at those temperatures can be obtained by algebraic addition. This method offers a great advantage in that the temperature need be only approximately constant and approximately known, since the differences in most cases amount to only a few microvolts. By this method the comparison can be very quickly made at 1500° in the blast-lamp flame, which, with a little care, can be made to give a temperature constant to 20°.

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* This Journal (4), xxviii, 300, 1909.

D. Fixed Points.—Considerable attention was given in the previous paper to the standard melting points which serve to establish the gas thermometer scale for general use. In particular, a study was made of the purity of the zinc, silver, gold, and copper used, and of the magnitude of the errors likely to arise with the ordinary metals obtainable in the market.* During the present work, attention has been more particularly directed to the technic of melting point determination itself.†

All the metal melting points here described, except that of palladium, were made in an upright cylindrical furnace through which passed a glazed porcelain tube which could be tightly closed above and below and therefore permitted the atmosphere about the melting metal to be perfectly controlled. An effort was first made to accomplish this by placing the entire furnace inside a gas-tight bomb in which the atmosphere could be similarly varied, but the persistent retention of gases by the various clay insulating materials used about the furnace made this method slow, cumbersome, and very uncertain in its results. The only success which these bomb furnaces attained was to permit melting points to be measured in an approximate vacuum (about 1^{mm} pressure). But it has since been found so much simpler to operate with a neutral or reducing atmosphere in the closed tube passing through the heated zone, that the vacuum furnace has not been used for this work.

The chief disadvantage in the use of a tube of this kind is its effect upon the temperature gradient along the furnace axis. More heat is diverted toward the ends of the furnace and the central constant temperature zone becomes shorter. It offers no difficulty except that greater care must be taken in locating the crucible within the constant temperature region.

The qualities desired in fixed thermometric points for establishing and reproducing a scale are:

(1) Exact reproducibility of the temperature in repeated determinations with the same charge of material and with a different charge independently obtained. This means that the metal or salt must be either perfectly pure or obtainable with a constant amount and kind of impurity.

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* E. T. Allen, in paper of Day and Clement, loc. cit., p. 454.

† See also W. P. White, Melting Point Determination and Melting Point Methods, this Journal (4), xxviii, 453 and 474, 1909.

(2) Independence of particular experimental arrangements. The melting point of a metal, for instance, must be sharp and definite enough so that with different kinds of furnaces and different rates of heating, the same temperature will be obtained.

(3) Convenience and safety of manipulation. A melting point which can only be obtained by the use of elaborate experimental arrangements is undesirable, even though it be reproducible and sharp. Furthermore, the substance must not injure the instrument to be calibrated.

(1) *Reproducibility.*—No extensive experiments have been made in the present work to test a large number of samples of different origin. It appeared sufficient to assure ourselves that all of the metals here used are obtainable in such degree of purity, or with such a constant amount of impurity, that the variations in their melting points are well within the limits of error in the scale itself. Waidner and Burgess* have recently made comparisons of various samples of pure zinc, antimony, and copper, and have found no differences exceeding 0·3°.† Our experience has been the same. All of the metals in the present investigation are readily obtainable from the ordinary sources of supply. They have been carefully analyzed in this laboratory by Dr. E. T. Allen, and the results are given in section 6.

(2) *Independence of Experimental Conditions.*—A number of experiments were made to test the effect of different experimental arrangements on the points. Two different furnaces were tried, one 65^{mm} inside diameter and 150^{mm} long, the other 55^{mm} inside diameter and 230^{mm} long. The region of constant temperature in the second furnace was longer than in the first and accordingly there was a larger range in which the crucible could be moved about without affecting the temperature. This furnace was used for all work after March 6, 1909. The ultimate test was always the agreement between the melting and freezing points. Any serious disagreement of these two shows that some influence is entering from without.

The results of the study were briefly as follows: (1) The best dimensions for a charge of metal are about 25^{mm} diameter by 45^{mm} deep. (2) The thermoelement tube should be about 5^{mm} above the bottom of the crucible. (3) There is a region within the furnace in which the melting and freezing points agree and are independent of the rate of heating or (within limits) of the depth of immersion of the thermoelement; it is necessary to find this position of the crucible by trial. With this position once determined, the temperature of the zinc, antimony, silver, gold, and copper points can be relied upon within 0·2°. With large charges and facilities for stirring the metal, Waidner and Burgess have found the zinc point to be reproducible in a given furnace, with a given sample, within less than 0·1°.

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* Phys. Rev., xxviii, 467, 1909. Bull. Bur. Stds., vi, 149–230, 1909.

† In the case of antimony, this statement applies only to Kahlbaum's metal.

White* showed that the temperatures of the two silicate points used for the present scale are reproducible within 1·0° independently of the dimensions of the furnace or the rate of heating. For a mineral melting point, the charge should be small (about 3 grams), the heat should approach the thermal junction from the side and not from the ends, and a position in the furnace should be found in which the melting point, determined by a bare thermoelement, does not vary with the rate of heating.

The possibility has been several times suggested that the temperature of the thermoelement inside of the tube might possibly be lower by a small constant amount than the temperature of the metal outside of the tube, and that this error might not be brought to light by such experiments as have been described. Several melting and freezing points of copper were, therefore, determined by enclosing the entire thermoelement wire in a thin capillary of silica glass which was slipped over the wire, bent double, and melted down upon the wire at the junction by heating in the oxyhydrogen flame. This was dipped directly into the molten copper to within 5^{mm} of the bottom, so that there was practically no possibility that the temperature of the junction could be lowered by radiation or conduction upward. The melting point on element D obtained in this way was 10,473 microvolts as compared with 10,473 microvolts in the closed glazed tube. There appears to be no error from this cause.

Convenience and Safety of Manipulation.—Zinc and gold are the most convenient of manipulation, as they require no special atmosphere and the temperatures are easily reached. Antimony, silver, and copper require an atmosphere of carbon monoxide and are somewhat less convenient. More care needs to be taken with copper than with silver and antimony because of the considerable effect of a very small amount of oxide. Antimony, silver, gold, and copper were all melted in carbon monoxide, made by dropping formic acid into warm sulphuric acid, and purified by passage through sodium hydroxide, lead nitrate, and sulphuric acid. The lead nitrate was introduced to make certain that no trace of hydrogen sulphide, which might be formed if the acid became too dilute or too warm, could pass into the metal.

The two silicates (diopside and anorthite) and palladium were melted in air. The silicate points are very convenient to arrange and manipulate, provided the furnace is well insulated so that the temperature can be reached without difficulty. Palladium strains the platinum resistance furnace near to its limit of endurance on account of the high temperature, but has the great convenience of not requiring a reducing atmosphere. Special pains need to be taken, however, in this case, to protect the thermoelement from contamination.

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* Diopside and its Relations to Calcium and Magnesium Metasilicates, this Journal (4), xxvii, p. 5, 1909.

Nickel and cobalt were melted in an atmosphere of hydrogen which was made by electrolysis in a large glass and earthenware generator, and purified by passage through potassium pyrogallate and sulphuric acid. Just before the thermoelement was introduced, the hydrogen was displaced by pure nitrogen drawn from a steel tank in which it was stored under pressure. The supply contained a trace of hydrogen and was, therefore, purified by passing over hot copper oxide and through calcium chloride and sulphuric acid. The extreme lightness of this gas compared with the outside air (especially when it is heated to 1450°) makes necessary special precautions in order to keep out any trace of air. Furthermore, hydrogen always caused contamination in the thermoelement, which was not prevented even when the hydrogen was replaced for a short time during the melting by pure nitrogen. Nickel and cobalt are, therefore, not recommended for frequent use in the calibration of thermoelements, if the two points, diopside and palladium (or diopside and anorthite), give a sufficient calibration for the purpose in hand.

The apparatus used for the melting points of nickel and cobalt is shown in section in fig. 6. The top of the large porcelain tube (Marquardt, glazed outside only) was closed by a sliding cup of brass in which the thermoelement tube and two others for introducing hydrogen were fastened by heating the cup and pouring in molten solder. The porcelain tube extended far enough out of the furnace to keep the brass cup cool. A groove near the base of the cup carried a piece of asbestos cord which made a gas-tight joint with the porcelain tube and permitted the whole to be raised and lowered without moving the crucible or opening the top of the tube. Two diaframs of Marquardt porcelain above the crucible also prevented any considerable radiation upward to the brass cup.

In zinc, antimony, silver, gold, and copper, the thermoelement was protected by a glazed Marquardt tube of 5^{mm} inside and 8^{mm} outside diameter. In the case of antimony, the tube was further protected by a thin tube of graphite which fitted into the cover of the crucible. With diopside and anorthite, some contamination from iridium in the furnace may take place, but can be largely prevented by surrounding the tube with pure platinum. A glazed Marquardt tube cannot be used in this case, for the glaze flows readily at these temperatures and may make its way into the charge. With nickel and cobalt, glazed Marquardt tubes and also pure magnesia tubes of the same size were used, but neither protects the element from contamination. In palladium only the pure magnesia tubes were used.

Fig. 6.

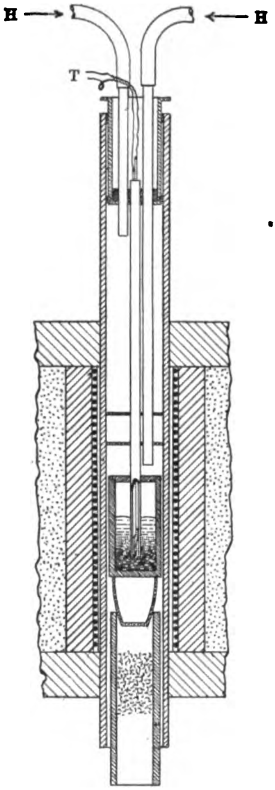

Fig. 6. The furnace in which the standard metal melting points were made, showing the position of the metal with respect to the coil, the thermoelement (T) and the arrangement (H) for maintaining a hydrogen or nitrogen atmosphere.

Zinc, antimony, silver, gold, and copper were melted in graphite crucibles 27^{mm} in diameter and 80^{mm} deep inside, and 37^{mm} in diameter and 100^{mm} high outside. The charge of metal was from 45^{mm} to 55^{mm} deep. Diopside and anorthite were melted in small platinum crucibles 10^{mm} in diameter and 18^{mm} deep, as described and illustrated in the paper already referred to.* Nickel was melted in an unglazed Marquardt porcelain crucible, lined with a paste consisting of about 90 per cent Al_2O_3 and 10 per cent MgO; and also in a Berlin "pure magnesia" crucible. The charge was about 25^{mm} in diameter and 30^{mm} deep. Cobalt could not be melted in the alumina lined crucible, as the metal penetrated through the lining and attacked the porcelain. It was, therefore, melted in a "pure magnesia" crucible made by the Königliche Porzellan Manufaktur. The material of these crucibles probably contains a small percentage of silica. Palladium was melted in a crucible made in this laboratory from a specially pure magnesia made by Baker and Adamson. The magnesia was first shrunk by heating to a temperature higher than that at which the crucible was to be used, and was then made into a paste with water and a little magnesium chloride, spun into form, and baked.

Particular details regarding each of the substances used will now be taken up in the order of their temperatures.†

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* W. P. White, this Journal (4), xxviii, 477, 1909.

† See, also, E. T. Allen, in paper of Day and Clement, loc. cit., p. 454.

Zinc.—Two samples of "C. P. sticks" were used, both from Eimer and Amend. No appreciable difference could be observed between their melting points. Both melting and freezing points were sharp and measurable to a fraction of a microvolt. Successive readings did not differ by more than one microvolt. The charge was about 200 grams. The analysis has been published.*

Antimony.—Two samples of metal were used, both from Kahlbaum, and no appreciable difference was found between their melting points. An analysis of the first sample is given in section 6. The charge weighed about 150 grams. The melting point is sharp and does not differ from the freezing point by more than one microvolt, provided the undercooling which always precedes solidification does not exceed 15°. If the metal is undercooled too far to give an accurate freezing point, the fact is easily recognized by observing that the thermoelement does not return to a sustained constant temperature, but merely rises to a maximum, then falls again. The amount of undercooling is greater the higher the metal has been heated above its melting point after the melting is complete.

Silver.—The charge weighed about 260 grams. Only one supply was used, a specially purified sample obtained from the Philadelphia Mint, of which an analysis is given in the previous paper.* The melting and freezing points were sharp and agreed within one microvolt.

Gold.—A new charge of gold was used, weighing 350 grams. This was obtained from Dr. Eckfeldt of the Philadelphia Mint. No analysis was deemed necessary.*

Copper.—The copper was obtained in the form known as "copper drops cooled in hydrogen" (Eimer and Amend). Only one supply was used. The melting and freezing points were not quite as sharp as was the case with silver, but always agreed within 1 microvolt. The temperature is very susceptible to a trace of oxide, which not only lowers the temperature appreciably but makes it more uncertain, so that if a little oxidation has taken place it is recognizable at once. Waidner and Burgess† found that the best commercial electrolytic copper showed an average difference of 0·2° in the melting point from the purified copper drops. Charge, about 210 grams.

Diopside.—Two samples of diopside were used, one from the preparation of Allen and White‡ and the other made up in 1909 by G. A. Rankin. No appreciable difference was found between the melting points. No freezing point can be obtained as the mineral undercools considerably. The charge used was 3 grams.

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* E. T. Allen, in paper of Day and Clement, p. 454.

† Loc. cit., p. 469 (Phys. Rev.); p. 174 (Bull.).

‡ This Journal (4), xxvii, 1, 1909.

Nickel.—A sample of specially purified electrolytic nickel was obtained from Kahlbaum. The analysis showed less than 0·2 per cent total impurities. Care must be taken in the case of nickel that no oxide forms, as a fairly sharp break can be observed about 10° below the melting point, which may represent the eutectic of nickel and nickel oxide. This break disappeared when the nitrogen was replaced for a few minutes by hydrogen. This lower point may easily be mistaken for the melting point of the metal, and this mistake seems to have occurred in several of the published determinations of the melting point of nickel. Nickel absorbs hydrogen aud possibly also nitrogen, and after cooling frequently showed excrescences and signs of "spitting" such as occur with silver in air.

Cobalt.—Kahlbaum's purest cobalt was used, containing less than 0·05 per cent total impurity. It was in the form of fine black powder, which was compressed into blocks for convenience in handling. The results obtained were not quite as satisfactory as with nickel on account of the higher temperature and more rapid contamination of the thermoelement. The absorption of gases seemed to be less than was the case with nickel.

Samples of Eimer and Amend's "98 to 99 per cent pure" nickel and cobalt were also tried. The difference between the two samples of nickel was not greater than the uncertainty in the melting point caused by contamination of the thermoelement. The "98–99 per cent pure" cobalt melted about 3·5° lower than the pure sample. Since the impurities in nickel are usually chiefly iron and cobalt, and those of cobalt are chiefly iron and nickel, and since the melting points of all three are close together, the melting points of the slightly impure metals can not be expected to lie far from those of the pure metals.

Anorthite.—Only one preparation of anorthite was used, made by G. A. Rankin 1909. The charge was about 3 grams. The melting point is not quite as sharp as that of diopside. Only the melting point can be obtained, as the mineral undercools considerably; it may even cool to glass without crystallization, in which case of course no melting point will be obtained on the following heating.

Palladium.—About 350 grams of pure palladium, in the form of sheet, was loaned to us by Dr. Heraeus. It melts and freezes quite sharply, making an excellent substance for a fixed thermometric point. The greatest uncertainty is caused by the vaporization of the metal and consequent contamination of the thermoelement wire. The charge used weighed 128–210 grams

In addition to the fixed points which have just been described, two other metal melting points, cadmium and aluminum, were incidentally determined. Only one measurement of the cadmium point was made on the gas thermometer, and this chiefly for the purpose of checking the extrapolation below the zinc point. The conditions of melting were the same as for zinc. The sample was obtained from Eimer and Amend, and its analysis has been given in a paper by Day and Allen.* The charge weighed 215 grams.

A sample of pure aluminum obtained from the Aluminum Company of America was melted in a graphite crucible of the usual size in an atmosphere of carbon monoxide. On account of the sensitiveness of aluminum to silicon contamination, the tube carrying the thermoelement was also provided with a thin protecting cover of graphite so that the metal came in contact only with pure graphite. The freezing point was sharp and constant. The melting point was less sharp but lay within 0·5° of the freezing point.

The effect on the final temperature of all the errors and corrections which have been discussed in this section, is shown in summarized form in Table IV.

The figures of Table IV serve to emphasize the statements already made, that the greatest present uncertainty in the high temperature gas scale arises from the lack of uniformity in an air bath, which not only leads to uncertainty as to what is the true temperature of the gas in the bulb, but also to errors in the transference by the thermoelement. The next largest uncertainty, due to the limitations of the materials used for fixed points, is not directly chargeable to the gas thermometer. In this connection, considerably more work needs to be done on the high thermometric points, comparable in thoroughness to the work in low temperature thermometry of Richards, Dickinson, and others, on the sodium sulphate transition point.

4. *Experimental Data and Calculated Results.*

A. Expansion Coefficient.—In Table V are given the experimental data on the expansion coefficients of the alloy 80 per cent platinum, 20 per cent rhodium. In the first column is given the date of the series, in the second and third columns the readings of the thermoelements at the middle of the bar, corrected for zero error and the temperature of the cadmium cell. The 12 other readings taken with each element at each temperature at different points along the bar cannot be given here, but the fourth and fifth columns contain the readings of the thermoelement corrected to represent the integrated tem-

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* Arthur L. Day and E. T. Allen, Phys. Rev., xix, 180, 1904.

TABLE IV.—*Estimated Errors and their Effect on the Value of t.*

Quantity affected	Source of error	Amount of error		Effect on t	
		at 400°	at 1500°	at 400°	at 1500°
(A) Temperature of gas	Temperature differences over bulb surface	2 mv.	5 mv.	± 0·2°	± 0·4°
	Variability	0	1 mv.	0	± 0·1°
(B) p_0	Reference point	0·02 mm.	0·02 mm.	± 0·04°	± 0·15°
"	Manometer setting	0·02 mm.	0·02 mm.	± 0·04°	± 0·15°
"	Scale corrections	0·01 mm.	0·01 mm.	± 0·02°	± 0·07°
"	Temperature of mercury	0·05 mm.	0·05 mm.	± 0·10°	± 0·38°
"	Barometer setting	0·03 mm.	0·03 mm.	± 0·06°	± 0·23°
"	Temperature of barometer	0·05 mm.	0·05 mm.	± 0·10°	± 0·38°
"	Variations in p_0	0	0–·05 mm.	0	0 to ±0·3
p	Reference point	0·02 mm.	0·02 mm.	± 0·02°	0
"	Manometer setting	0·02 mm.	0·02 mm.	± 0·02°	0
"	Scale corrections	0·02 mm.	0·02 mm.	± 0·02°	0
"	Temperature mercury	0·07 mm.	0·20 mm.	± 0·07°	± 0.05°
"	Barometer setting	0·03 mm.	0·03 mm.	± 0·03°	± 0·01°
"	Barometer temperature	0·05 mm.	0·05 mm.	± 0·05°	± 0·01°
"	Unheated space v_1	0·020 cc.	0·020 cc.	± 0·07°	± 0·5°
	t_1	0·5–50°	0·5°–100°	± 0·01°	± 0·1°
β	Temperature	1·0°	2·0°	± 0·02°	± 0·11°
"	Expansion	0·005 mm.	0·008 mm.	± 0·02°	± 0·09
"	Hysteresis in expansion	0·01 mm.	0·01 mm.	± 0·04°	± 0·10°
(C) E.M.F.	Instrumental correction	1 mv.	2 mv.	± 0·1°	± 0·2°
"	Contamination	0	0–12 mv.	0	0 to +1·0°
"	Integration over bulb	3 mv.	12 mv.	± 0·3°	± 1·0°
(D) Fixed points	Instrumental corrections	1 mv.	2 mv.	± 0·1°	± 0·2°
"	Contamination	0	0–10 mv.	0	0 to –1·0°
"	Variation in given charge	Specific 1 – 10 mv.		Specific 0·1 – 1·0°	
"	Variation between different charges	Specific 1 – 20 mv.		Specific 0·1 – 2·0°	

perature along the bar. For convenience, the integration was made in terms of microvolts instead of degrees. The sixth and seventh columns contain the temperatures corresponding

TABLE V.—*Observations of Expansion Coefficient, β.*

Date	Thermoelements				Temperature			Expansion from 0°	
	W	Z	W cor.	Z cor.	by W	by Z	Mean	mm on 500 mm	$10^6\beta$
1908									
Sept. 21	2261	2251	2312	2298	301·4°	301·4°	301·4°	1·404	9·32
	3197	3187	3273	3258	404·6	405·4	405·0	1·912	9·44
	4169	4153	4257	4237	506·0	507·1	506·6	2·434	9·61
	5157	5140	5237	5212	603·9	605·1	604·5	2·950	9·76
	6197	6178	6286	6262	705·4	707·2	706·3	3·500	9·91
	7264	7238	7362	7333	806·2	807·8	807·0	4·064	10·07
	8361	8335	8457	8420	905·9	906·7	906·3	4·640	10·24
	9509	9470	9599	9552	1006·9	1006·8	1006·8	5·241	10·41
	10662	10611	10733	10675	1104·5	1103·4	1104·0	5·828	10·56
	11963	11896	12018	11921	1215·3	1210·2	1212·8	6·469	10·67
Sept. 25	1817	1801	1848	1831	248·7	248·4	248·6	1·154	9·28
	2756	2735	2791	2768	353·4	352·9	353·2	1·666	9·43
	3699	3674	3726	3702	451·8	452·0	451·9	2·158	9·55
	4686	4655	4691	4662	549·7	550·3	550·0	2·668	9·70
	5711	5679	5691	5660	648·2	649·2	648·7	3·191	9·84
	6820	6788	6772	6742	751·2	752·6	751·9	3·757	9·99
	7847	7813	7754	7720	842·2	843·2	842·7	4·262	10·11
	8980	8945	8845	8809	940·8	941·4	941·1	4·827	10·26
	10140	10102	9939	9901	1036·4	1037·0	1036·8	5·403	10·42
	11368	11327	11109	11063	1136·9	1136·4	1136·7	6·012	10·58
Oct. 3	2291	2272	2302	2283	300·3	299·8	300·1	1·384	9·22
	3228	3205	3250	3228	402·2	402·2	402·2	1·899	9·44
	4208	4181	4243	4215	504·6	504·9	504·8	2·432	9·63
	5205	5175	5247	5216	604·8	605·5	605·2	2·964	9·79
	6238	6206	6281	6249	704·9	705·9	705·4	3·511	9·95
	7297	7263	7342	7309	804·4	805·5	805·0	4·069	10·11
	8401	8365	8446	8408	904·9	905·6	905·3	4·644	10·26
	9536	9497	9576	9534	1004·9	1005·2	1005·1	5·231	10·41
	10675	10647	10710	10670	1102·6	1103·0	1102·8	5·830	10·57
	11884	11857	11926	11875	1207·5	1206·2	1206·8	6·466	10·71
Oct. 29	8419	8377	8366	8324	897·4	898·0	897·7	4·618	10·29
	9551	9507	9436	9392	992·6	992·8	992·7	5·169	10·41
	10706	10663	10539	10496	1088·0	1088·2	1088·1	5·752	10·57
	11884	11849	11786	11751	1195·6	1195·7	1195·7	6·401	10·70
	13137	13104	13134	13101	1309·9	1309·8	1309·9	7·154	10·92
1909	W	D	W cor.	D cor.	by W	by D			
Oct. 13	2304	2301	2235	2232	293·0	293·0	293·0	1·352	9·23
	6222	6217	6180	6175	695·2	695·9	695·6	3·452	9·92
	9501	9494	9493	9486	997·6	998·1	997·9	5·190	10·40
Oct. 14	9540	9536	9542	9544	1001·9	1003·1	1002·5	5·200	10·37
	10666	10663	10690	10691	1101·9	1102·5	1102·2	5·811	10·54
	11839	11836	11783	11783	1195·4	1195·7	1195·6	6·410	10·72
	12998	12993	13121	13120	1308·9	1308·6	1308·8	7·156	10·93
	14183	14170	14390	14372	1413·4	1411·6	1412·5	7·832	11·09

to the readings in columns 4 and 5, and the eighth column, the mean of these two temperatures. The micrometer readings are not given, but in column 9 will be found the expansions reduced to millimeters for that portion of the bar lying between the 0 and 50^{cm} marks on the ends. Each of these represents the mean of eight settings at each end of the bar. In the last column are given the values of the mean expansion coefficient from 0°, calculated by dividing the expansion by the length at 0 and by the temperature.

For convenience of comparison, the values of β at the nearest round temperatures were interpolated linearly between the observations in each series, and the results are given in Table VI. Values interpolated between these values are given in parentheses.

TABLE VI.—*Values of* 10^6 β *at Round Temperatures for the alloy 80 Pt, 20 Rh.*

Temp.	21 Sept. 1908	25 Sept. 1908	3 Oct. 1908	29 Oct. 1908	13 Oct. 1909	14 Oct. 1909	Mean
250		9·28					
300	9·31	(9·36)	9·22		9·24		9·28
350	(9·37)	9·43	(9·33)		(9·33)		9·36
400	9·43	(9·49)	9·44		(9·41)		9·44
450	(9·52)	9·55	(9·53)		(9·50)		9·52
500	9·60	(9·62)	9·62		(9·58)		9·61
550	(9·67)	9·70	(9·71)		(9·67)		9·69
600	9·75	(9·77)	9·79		(9·76)		9·77
650	(9·83)	9·84	(9·86)		(9·84)		9·84
700	9·90	(9·92)	9·94		9·93		9·92
750	(9·98)	9·99	(10·02)		(10·01)		10·00
800	10·06	10·06	10·10		(10·09)		10·08
850	(10·14)	10·12	(10·17)		(10·16)		10·15
900	10·23	(10·20)	10·25	10·29	(10·24)		10·24
950	(10·31)	10·27	(10·32)	(10·36)	(10·32)		10·32
1000	10·40	(10·36)	10·40	10·42	10·40	10·37	10·39
1050	(10·47)	10·44	(10·48)	(10·50)		(10·45)	10·47
1100	10·55	(10·52)	10·57	10·59		10·54	10·55
1150	(10·60)	10·60	(10·64)	(10·65)		(10·63)	10·62
1200	10·65	(10·67)	10·71	10·71		10·73	10·69
1250				(10·81)		(10·82)	10·81
1300				10·90		10·92	10·91
1350				(10·99)		(10·99)	10·99
1400						11·07	11·07
1450							(11·15)
1500							(11·23)

The table shows that the percentage error at 300° is greater than that at 1200° and above, probably on account of the larger effect of the hysteresis in the expansion and contraction, already discussed on page 114. The agreement of the results is very satisfactory, particularly in view of the fact that each series represents an entirely different curve of temperature variation along the bar. In some cases the temperatures at the ends were lower than at the middle, in others higher than at the middle, and in one series one end was higher and the other lower. The mean of all, therefore, probably eliminates any error which might arise from variation of temperature along the bar.

The results are represented within the limits of error by the straight line equation:

$$10^6\beta = 8{\cdot}79 + 0{\cdot}00161t.$$

This may be compared here with the expansion coefficients between 300° and 1000° determined by the authors for the 10 per cent iridium alloy,* and of Holborn and Day† for the 20 per cent iridium alloy and for pure platinum:

80 Pt. 20 Ir. $10^6\beta = 8{\cdot}20 + 0{\cdot}00142t$
90 Pt. 10 Ir. $10^6\beta = 8{\cdot}84 + 0{\cdot}00131t$
Pt. $10^6\beta = 8{\cdot}87 + 0{\cdot}00132t.$

B. Gas Thermometer Data and Fixed Points.—In Table VII are given the observed gas thermometer data.‡ In the first column is the date of the measurement. The measurements are numbered chronologically in the second column for convenience of reference. In the third column is the measured pressure, p' (or p_0') in millimeters of mercury at 0°, corrected as described on pages 107 and 108. The application of the correction for unheated space (see p. 108) gives the pressure p (or p_0) which is found in the fourth column. In the fifth column is the value of the temperature, t, calculated by formula (5) on page 101. In column 6 are given the readings of the standard thermoelements in microvolts, and in column 7 the positions of these elements on the bulb; for the significance of these figures see fig. 1 and note on page 104. In the last column are given the other elements which were used on the bulb, together with their positions designated in the same way. The italicized letters represent single platinum wires instead of thermoelements.

A few measurements in which the value of p_0 changed by more than 0·1 per cent have been omitted; their position is shown by the absence of their corresponding serial numbers.

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* Published in paper of Day and Clement, loc. cit, pp. 425–441.

† This Journal (4), xi, 374, 1901.

‡ For the measurements in the table, seven furnaces were employed, using three supplies of platinum wire of about 400 grams each. One of these furnaces was wound on the outside, the other six on the inside of the tube. It was possible to rewind the wire at least once after the furnace had burned out. Failure always occurred several cms. away from the bulb in the end portions of the furnace, which, in order to secure uniformity of temperature over the bulb, had to be considerably superheated. Only one measurement was made at the palladium point, as this one rendered the furnace unfit for further use; the conditions of this measurement, were, however, perfect.

TABLE VII—*Observed Gas-Thermometer Data.*

Date	No.	p' (or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
1908			GAS FILLING NO. 1				
30 Nov.	1	217·65	217·63	0°	----		
"	2	1037·77	1042·72	1079·87	W10443 X 10491	4 8	Z (1), S (9)
1 Dec.	3	217·45	217·43	0	----		
2 Dec.	5	217·10	217·08	0	----		
3 Dec.	6	948·81	952·84	960·59	W 9061 X 9100	4 8	Z (1), S (9)
4 Dec.	7	217·12	217·10	0	----		
16 Dec.	8	217·08	217·06	0	---		
17 Dec.	9	1038·50	1043·48	1083·61	W10483 X 10555	4 8	Z (1), S (9)
18 Dec.	10	217·18	217·16	0	----		
19 Dec.	11	1038·57	1043·56	1083·77	W10473 X 10512	4 8	Z (1), S (9)
21 Dec.	12	217·06	217·04	0	----		
23 Dec.	15	217·49	217·47	0	----		
24 Dec.	16	1242·38	1249·71	1365·71	A 13866 X ----	4 8	Y (1), S (9)
28 Dec.	17	217·57	217·55	0	----		
1909 22 Jan.	18	1039·78	1044·74	1082·84	A 10502 Y 10612	4 8	Z (9), *B* (1·3) *W* (2·3), *S* (6·7) *X* (7·3)
"	19	1038·82	1043·79	1081·87	A 10506 Y 10584	4 8	Do.
"	20	1037·85	1042·83	1080·89	A 10498 Y 10555	4 8	Do.
23 Jan.	21	217·36	217·34	0	----		
25 Jan.	22	543·01	544·07	418·40	A 3414 Y 3436	4·5 8	Do.
"	23	542·27	543·32	417·43	A 3408 Y 3435	4·5 8	Do.
26 Jan.	24	703·78	705·81	629·80	A 5510 Y 5550	4·5 8	Do.
"	25	702·64	704·67	628·34	A 5501 Y 5529	4·5 8	Do.
"	26	949·56	953·63	960·22	A 9090 Y 9159	4·5 8	Do.
"	27	948·15	952·23	958·41	A 9075 Y 9119	4·5 8	Do.
"	28	1039·03	1044·05	1083·01	A 10515 Y 10593	4·5 8	Do.
"	29	1037·92	1042·93	1081·56	A 10505 Y 10556	4·5 8	Do.
27 Jan.	30	217·33	217·31	0°	----		
28 Jan.	31	542·87	543·92	418·30	A 3410 Y 3436	4·5 8	Do.
"	32	542·07	543·11	417·25	A 3404 Y 3425	4·5 8	Do.
"	33	704·06	706·07	630·21	A 5514 Y 5553	4·5 8	Do.

TABLE VII—(*Continued*)

Date	No.	p' (or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
28 Jan.	34	703·35	705·37	629·31	A 5510 Y 5537	4·5 8	Z (9), *B* (1·3), *W* (2·3), *S* (6·7) *X* (7·3)
"	35	948·96	953·05	959·46	A 9087 Y 9142	4·5 8	Do.
"	36	949·86	953·97	960·69	A 9098 Y 9163	4·5 8	Do.
"	37	1038·50	1043·57	1082·23	A 10511 Y 10576	4·5 8	Do.
"	38	1038·99	1044·06	1082·90	A 10512 Y 10585	4·5 8	Do.
"	39	1039·61	1044·68	1083·68	A 10509 Y 10617	4·5 8	Do.
29 Jan.	40	217·37	217·35	0°	----		
"	41	949·32	953·38	959·78	A 9086 Y 9156	4·5 8	Do.
"	42	948·58	952·66	958·81	A 9085 Y 9131	4·5 8	Do.
"	43	1039·29	1044·34	1083·15	A 10515 Y 10595	4·5 8	Do.
"	44	1038·49	1043·56	1082·09	A 10511 Y 10568	4·5 8	Do.
"	45	1039·63	1044·71	1083·58	A 10508 Y 10617	4·5 8	Do.
30 Jan.	46	217·39	217·37	0	----		
GAS FILLING No. 2							
18 Feb.	47	346·74	346·70	0	----		
22 Feb.	48	346·78	346·74	0	----		
23 Feb.	49	745·09	746·19	319·55	A 2487 D 2483 Z 2462	4·5 4·5 8	*W* (1·3), *B* (2·2), *X* (6·2), *S* (7·3), Y (12)
"	50	866·47	868·15	418·40	A 3414 D 3406 Z 3385	4·5 4·5 8	Do.
"	51	995·97	998·38	524·71	A 4451 D 4439 Z 4418	4·5 4·5 8	Do.
"	52	1122·39	1125·61	629·37	A 5510 D 5495 Z 5463	4·5 4·5 8	Do.
24 Feb.	53	346·67	346·63	0	----		
26 Feb.	59	346·24	346·20	0	----		
"	60	1657·03	1665·07	1083·17	A 10508 D 10473 Z 10422	4·5 4·5 8	*W* (3·3), *B* (2·2), *X* (6·2), *S* (7·2), Y (12)
27 Feb.	61	346·45	346·41	0	----		
1 Mar.	62	1388·84	1394·13	853·76	A 7895 D 7869 Z 7829	4.5 4.5 8	*B* (3·2), *W* (2·3), *X* (6·2), *S* (7·2,) Y (12)
"	63	1513·67	1520·20	960·29	A 9086 D 9055 Z 9010	4·5 4·5 8	Do.
"	64	1632·03	1639·78	1062·15	A 10265 D 10229 Z 10178	4·5 4·5 8	Do.

TABLE VII—(*Continued*)

Date	No.	p'(or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
1 Mar.	65	1655·77	1663·81	1082·84	A 10511	4·5	*B* (3·2), *W* (2·3), *X* (6·2), *S* (7·2), Y (12)
					D 10474	4·5	
					Z 10420	8	
2 Mar.	66	346·20	346·17	0	----		
3 Mar.	67	1386·28	1391·55	852·44	A 7885	4·5	*W* (3·3), *B* (2·2) *X* (6·2), *S* (7·2) Z (8), Y (12)
					D 7861	4·5	
					Z 7820	8	
"	68	1511·95	1518·48	959·81	A 9088	4·5	Do.
					D 9059	4·5	
					Z 9013	8	
"	69	1628·71	1636·46	1060·24	A 10257	4·5	Do.
					D 10221	4·5	
					Z 10169	8	
"	70	1654·46	1662·50	1082·73	A 10511	4·5	Do.
					D 10478	4·5	
					Z 10444	8	
5 Mar.	71	345·98	345·94	0	---		
GAS FILLING NO. 3							
4 June	72	345·31	345·27	0	----		
"	73	861·67	862·94	417·07	A 3403	4·1	Y (1), *a* (2·4), *b* (6·4)
					E 3419	4·3	
					F 3414	4·5	
					G 3416	4·7	
					Z 3370	8	
"	74	1118·50	1120·83	629·11	A 5516	4·1	Do.
					E 5535	4·3	
					F 5528	4·5	
					G 5529	4·7	
					Z 5461	8	
5 June	75	345·31	345·27	0	----		
"	76	1510·50	1515·27	959·77	A 9090	4·1	Do.
					E 9114	4·3	
					F 9099	4·5	
					G 9108	4·7	
					Z 9002	8	
"	77	1628·08	1633·64	1060·53	A 10258	4·1	Do.
					E 10285	4·3	
					F 10266	4·5	
					G 10279	4·7	
					Z 10161	8	
"	78	1652·36	1658·10	1081·28	A 10503	4·1	Do.
					E 10529	4·3	
					F 10510	4·5	
					G 10523	4·7	
					Z 10404	8	
7 June	79	345·50	345·46	0	----		
10 June	80	345·52	345·48	0	----		
18 June	81	1512·96	1517·69	961·21	F 9129	4·1	*a* (1), *b* (2·4), *c* (6·4), *e* (7·3)
					E 9128	4·3	
					A 9080	4·5	
					G 9122	4·7	
					Z 9015	8	
"	82	1630·94	1636·53	1062·53	F 10299	4·1	Do.
					E 10300	4·3	
					A 10252	4·5	
					G 10292	4·7	
					Z 10181	8	

TABLE VII—(*Continued*)

Date	No.	p'(or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
18 June	83	1653·61	1659·37	1082·14	F 10534	4·1	*a* (1), *b* (2·4) *c* (6·4), *e* (7·3)
					E 10534	4·3	
					A 10487	4·5	
					G 10526	4·7	
					Z 10403	8	
"	84	1654·51	1660·27	1082·91	F 10536	4·1	Do.
					E 10534	4·3	
					A 10485	4·5	
					G 10525	4·7	
					Z 10426	8	
19 June	85	345·51	345·47	0	----		
GAS FILLING No. 3a							
19 June	86	219·73	219·71	0	---		
"	87	710·34	711·83	627·61	F 5520	4·1	*a* (1), *e* (2·3) *c* (6·3), *f* (7·3)
					E 5520	4·3	
					A 5484	4·5	
					G 5516	4·7	
					Z 5437	8	
"	88	962·21	965·23	961·71	F 9139	4·1	Do.
					E 9136	4·3	
					A 9089	4·5	
					G 9131	4·7	
					Z 9036	8	
"	89	1051·74	1055·41	1082·75	F 10540	4·1	Do.
					E 10538	4·3	
					A 10490	4·5	
					G 10531	4·7	
					Z 10428	8	
21 June	90	219·74	219·72	0	----		
22 June	92	220·65	220·63	0	----		
24 June	93	220·62	220·59	0	----		
25 June	95	220·56	220·53	0	---		
2 July	96	1288·36	1288·82	1391·97	H 14251	4·1	Do.
					E 14227	4·3	
					F 14222	4·5	
					G 14245	4·7	
					Z 14121	8	
"	97	1285·43	1290·89	1394·89	H 14282	4·1	Do.
					E 14247	4·3	
					F 14241	4·5	
					G 14274	4·7	
					Z 14156	8	
3 July	98	221·02	220·99	0	----		
"	99	1281·97	1287·45	1393·34	H 14213	4·1	Do.
					E 14214	4·3	
					F 14196	4·5	
					G 14216	4·7	
					Z 14099	8	
"	100	1284·05	1289·54	1396·17	H 14264	4·1	Do.
					E 14242	4·3	
					F 14235	4·5	
					G 14259	4·7	
					Z 14156	8	
6 July	101	220·62	220·60	0	----		

TABLE VII—(*Continued*)

Date	No.	p'(or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
GAS FILLING No. 4							
8 July	102	216·81	216·79	0	----		
"	103	1261·35	1266·80	1391·15	H 14235 E 14216 F 14209 G 14222 Z 14124	4·1 4·3 4·5 4·7 8	*a* (1), *e* (2·3) *c* (6·3), *f* (7·3)
"	104	1263·13	1268·59	1393·55	H 14249 E 14229 F 14199 G 14236 Z 14155	4·1 4·3 4·5 4·7 8	Do.
9 July	105	217·36	217·33	0	----		
"	106	1261·71	1267·15	1391·64	H 14251 E 14236 F 14233 G 14241 Z 14123	4·1 4·3 4·5 4·7 8	Do.
"	107	1263·01	1268·46	1393·44	H 14240 E 14236 F 14225 G 14233 Z 14152	4·1 4·3 4·5 4·7 0	Do.
10 July	108	217·35	217·33	0			
"	109	1306·60	1312·52	1455·37	H 15019 E 15020 F ---- G ---- Z 14903	4·1 4·3 4·5 4·7 8	Do.
12 July	110	217·36	217·34	0	----		
"	111	1305·53	1311·35	1458·52	H 14978 E 14980 F ---- G --- Z 14867	4·1 4·3 4·5 4·7 8	Do.
"	112	1305·46	1311·28	1453·31	H 14980 E 14960 F 14947 G - -- Z 14872	4·1 4·3 4·5 4·7 8	Do.
13 July	113	217·40	217·38	0	----		
10 Sept.	114	217·38	217·36	0	----		
11 Sept.	115	1328·68	1334·79	1484·70	H ---- E 15389 F 15374 G ---- A 15357	4·1 4·3 4·5 4·7 8	*a* (1), *c* (2·3) *e* (6·7), *f* (7·3)
"	116	1332·18	1338·32	1489·60	H --- E 15411 F 15417 G 15418 A 15421	4·1 4·3 4·5 4·7 8	Do.
13 Sept.	117	217·62	217·60	0	----		

TABLE VII—(*Continued*)

Date	No.	p'(or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
15 Sept.	118	1329·92	1336·03	1487·36	H	4·1	*a* (1), *c* (2·3) *e* (6·7) *f* (7·3)
					E 15391	4·3	
					F 15389	4·5	
					G 15399	4·7	
					A 15382	8	
16 Sept.	119	217·51	217·49	0	....		
17 Sept.	120	1329·68	1335·78	1486·95	H	4·1	Do.
					E 15386	4·3	
					F 15376	4·5	
					G 15368	4·7	
					A 15379	8	
"	121	1331·40	1337·51	1489·34	H	4·1	Do.
					E 15397	4·3	
					F 15396	4·5	
					G 15389	4·7	
					A 15412	8	
18 Sept.	122	217·52	217·50	0	....		
21 Sept.	123	1306·75	1312·72	1454·83	H	4·1	Do.
					E 14991	4·3	
					F 14996	4·5	
					G 14957	4·7	
					A 14982	8	
"	124	1307·28	1313·25	1455·60	H	4·1	Do.
					E 14979	4·3	
					F 14984	4·5	
					G 14952	4·7	
					A 14996	8	
22 Sept.	125	217·45	217·43	0	....		
27 Nov.*	126	1045·80	1049·49	1090·59	H 10618	4·1	*a* (1·5), J (2·4) *c* (6·2), *e* (7·2)
					E 10626	4·3	
					F 10622	4·5	
					G 10616	4·7	
					C 10567	8	
29 Nov.	127	217·28	217·26	0	....		
9 Dec.	128	1129·52	1133·91	1206·63	H 12002	4·1	Do.
					E 12006	4·3	
					F 12003	4·5	
					G 12010	4·7	
					C 11914	8	
"	129	1194·81	1199·74	1298·01	H 13106	4·1	Do.
					E 13112	4·3	
					F 13107	4·5	
					G 13115	4·7	
					C 13007	8	
"	130	1261·16	1266·68	1391·45	H 14246	4·1	Do.
					E 14250	4·3	
					F 14248	4·5	
					G 14256	4·7	
					C 14146	8	
10 Dec.	131	217·30	217·28	0	....		
20 Dec.	132	1125·92	1130·29	1201·50	H 11940	4·1	*a* (1), J (2·3), *c* (6·2), *e* (7·1)
					E 11946	4·3	
					F 11951	4·5	
					G 11949	4·7	
					C 11887	8	

* Outside-wound furnace. See page 106.

TABLE VII—(*Concluded*)

Date	No.	p' (or p_0')	p (or p_0)	t	Standard Elements	Position	Other elements and positions
20 Dec.	133	1302·40	1308·33	1450·03	H 14950 E 14958 F 14962 G 14955 C 14882	4·1 4·3 4·5 4·7 8	*a* (1), J (2·3) *c* (6·2), *e* (7·1)
"	134	1372·16	1378·78	1550·15	H 16156 E 16160 F 16170 G 16148 C 16075	4·1 4·3 4·5 4·7 8	Do.
21 Dec.	135	217·29	217·27	0	----		

(*Continued from p. 132.*)

The melting and freezing points of the metals and salts, measured with the various thermoelements used during the investigation, as well as the frequent comparisons of thermoelements with each other, are too numerous to be published here, especially as they are practically all summarized in Table VIII. Table VIII contains the final temperature of each thermometric point studied. In the first column is the number of the experiment corresponding to that in Table VII. In the second column is the correction in degrees to be applied to each of the thermoelement readings on the *outside* of the bulb, integrated from the readings of the auxiliary elements as described on page 119; in the third column is given the corresponding correction in microvolts. In the fourth column are the readings of the standard elements on the *outside* of the bulb, corrected as above mentioned. In the fifth column are the readings of the same thermoelements at the fixed point in question, as obtained in the melting or freezing of metal or salt; these figures usually represent the mean of a considerable number of determinations.

In the sixth and seventh columns are the corresponding figures for the element *inside* of the bulb. In this case, however, no correction has been applied to the reading of the element, since, being located practically at the center of the bulb, it might be expected to represent the mean temperature of the entire volume of the bulb.

In the eighth and ninth columns are the temperatures of the fixed points derived from the preceding four columns. In the last column is given the weight assigned to each measurement. In assigning these weights the number of standard thermoelements used, the amount of variation in p_0, and other incidental variables were taken into consideration.

As has been pointed out on page 116, the relative weights to be assigned to the inside and outside elements are different at different temperatures; (1) on account of the difference in contamination, and (2) on account of the fact that the inside element is subject to the influence of conduction and radiation from below. The weights assigned were as follows:

Temperatures	Outside Element	Inside Element
400–1100°	3	1
1100–1300°	2	1
1300–1550°	1	1

The final weighted mean of the inside and outside elements is given at the head of each section of the table.

In the last section of the table are given various points which were determined to aid in interpolating between the fixed points by means of the thermoelement.

The only comment which need be made here on the data in Table VIII concerns the figures given under the heading "copper point." In this section of the table, the values derived at the two different initial pressures ($217–221^{mm}$ and $346–347^{mm}$) are quoted separately in order to bring out the fact that the difference between the temperatures obtained from these two pressures is less than the experimental error. In the other sections of the table the data obtained at the two pressures are not separately arranged. Above the copper point only the low pressure was used, as the high pressure would have exceeded the range of the manometer.

The significance of the comparison between the inside-and outside-wound furnaces, which appears in the first half of the section on the copper point, has been commented on elsewhere (see p. 106).

5. *Interpolation Between the Fixed Points.*

The preparation of formulae to represent the relation between the temperature defined by the gas thermometer and the electromotive force of a thermoelement has always been a cause of considerable dissatisfaction, both to the maker and the user. The chief reason for this is perhaps the fact that the formulae used have been applicable only to limited portions of the curve and have therefore given no suggestion of physical significance. In the Reichsanstalt publication* the data extended from 300° to 1100° and included several good fixed points (melting points of pure metals) between which no interpolation, however rough, could go far astray. Accordingly, in so far as interpolation was concerned, but little attention required to be given to the formulation of this relation. It was sufficient that a simple formula of the form

$$E = -a + bt + ct^2$$

could be made to represent the observations between 300° and 1100° within the limits of the errors of observation.

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* Holborn and Day, 1900, loc. cit.

TABLE VIII—*Temperatures of the Fixed Points.*

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Degr's	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	
				Zinc Point. 418·2°					
22	0·0°	0	A 3414	3411	Y 3436	3436	418·1°	418·4°	2
23	−0·3	−3	A 3405	3410·5	Y 3445	3435	418·0	418·4	2
31	0·0	0	A 3410	3410·5	Y 3436	3435	418·3	418·2	2
32	−0·2	−2	A 3402	3410	Y 3425	3434	418·0	418·1	2
50	−0·1	−0·5	A 3413	3411			418·2		
			D 3405·5	3406	Z 3384·5	3382	418·4		
							418·3	418·2	3
73	−0·2	−2	A 3401	3413·5			418·4		
			E 3417	3429			418·3		
			F 3412	3429			418·8		
			G 3414	3429	Z 3370	3382	418·6		
							418·5	418·3	4
					Weighted Mean,		418·2°	418·3°	
				Antimony Point. 629·2°					
24	−0·1	−1	A 5509	5503	Y 5550	5546	629·2°	629·4°	2
25	−0·5	−5	A 5496	5503	Y 5529	5545	629·0	629·9	2
33	−0·1	−1	A 5513	5503	Y 5553	5544	629·2	629·3	2
34	−0·5	−5	A 5505	5503	Y 5537	5543	629·1	629·9	2
52	−0·5	−5	A 5505	5503			629·6		
			D 5490	5492	Z 5463	5460	629·2		
							629·4	629·1	2
74	−0·2	−2	A 5514	5504			628·2		
			E 5533	5530			628·8		
			F 5526	5530			629·5		
			G 5527	5530	Z 5461	5461	629·4		
							629·0	629·1	4
87	−0·3	−3	F 5517	5530			628·9		
			E 5517	5530			628·9		
			A 5481	5504			629·9		
			G 5513	5530	Z 5437	5461	629·3		
							629·2	629·9	4
					Weighted Mean,		629·1°	629·5°	
				Silver Point. 960·0°					
6	+0·8	+9	W9070	9057	X 9100	9071	959·4°	958·0°	1
26	−0·3	−3	A 9087	9083	Y 9159	9141	959·9	958·6	2
27	−0·8	−9	A 9066	9083	Y 9119	9141	959·9	960·4	2
35	−0·7	−8	A 9079	9082	Y 9142	9141	959·7	959·4	1
36	−0·1	−1	A 9097	9082	Y 9163	9141	959·4	958·7	1
41	−0·3	−3	A 9083	9081	Y 9156	9141	959·6	958·5	2
42	−0·8	−9	A 9076	9081	Y 9131	9141	959·3	959·7	2
63	−0·6	−7	A 9079	9084			960·7		
			D 9048	9058	Z 9010	9019	961·2		
							960·9	961·1	2

TABLE VIII—(*Continued*)

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Degr's	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	
				Silver Point—(Cont.)					
68	−0·7	−8	A 9080	9085			960·3°		
			D 9051	9058	Z 9013	9019	960·4		
							960·4	960·3°	2
76	−0·2	−2	A 9088	9082			959·2		
			E 9112	9113			959·7		
			F 9097	9113			961·2		
			G 9106	9111	Z 9002	9018	960·2		
							960·1	961·2	4
81	+0·3	+3	F 9132	9113			959·5		
			E 9131	9113			959·6		
			A 9083	9082			961·1		
			G 9125	9111	Z 9015	9018	960·0		
							960·0	961·5	4
88	+0·3	+3	F 9143	9113			959·0		
			E 9139	9113			959·4		
			A 9093	9082			960·7		
			G 9135	9112	Z 9026	9018	959·6		
							959·7	960·1	4
					Weighted Mean,		959·9°	960·2°	
				Gold Point. 1062·4°					
64	−0·3	−3	A 10262	10265			1062·4°		
			D 10226	10233	Z 10178	10193	1062·8		
							1062·6	1063·4°	2
69	−0·4	−4	A 10253	10266			1061·4		
			D 10217	10234	Z 10169	10193	1061·7		
							1061·6	1062·3	2
77	−0·3	−3	A 10255	10263			1061·2		
			E 10282	10295			1061·6		
			F 10263	10296			1063·4		
			G 10276	10294	Z 10161	10193	1062·1		
							1062·1	1063·3	4
82	+0·4	+4	F 10303	10296			1061·9		
			E 10304	10295			1061·8		
			A 10256	10263			1063·1		
			G 10296	10294	Z 10181	10193	1062·4		
							1062·3	1063·6	4
					Weighted Mean,		1062·2°	1063·2°	
			Copper Point. 1082·6° (*Lower Pressure.* $p_0 = 217-221^{mm}$)						
2	+1·2	+14	W10457	10478	X 10491	....	1081·7	....	1
9	+1·0	+12	W10495	10478	X 10555	....	1082·2	....	1
11	+1·2	+14	W10487	10478	X 10512	...	1083·1	....	1
18	+0·7	+ 8	A 10510	10502	Y 10612	10573	1082·2	...	2
19	−0·4	− 5	A 10501	10502	Y 10584	10573	1082·0	1081·0	3

TABLE VIII—(*Continued*)

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Degr's	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	
					Copper Point (Lower Pressure)—Cont.				
20	−0·8	− 9	A 10488	10502	Y 10555	10573	1082·1°	1082·5°	3
28	−0·3	− 4	A 10512	10501	Y 10593	10573	1082·1	1081·4	3
29	−0·9	−10	A 10494	10501	Y 10556	10573	1082·2	1083·0	3
37	−0·6	− 7	A 10504	10501	Y 10576	10573	1082·0	1082·0	2
38	−0·3	− 4	A 10509	10500	Y 10585	10573	1082·2	1081·9	2
39	+0·7	+ 8	A 10517	10500	Y 10617	..	1082·3	....	2
43	−0·3	− 4	A 10512	10500	Y 10595	10573	1082·2	1081·3	8
44	−0·9	−10	A 10501	10499	Y 10568	10573	1082·0	1082·6	3
45	+0·6	+ 7	A 10515	10499	Y 10617	----	1082·3	----	2
89	+0·5	+ 6	F 10546	10534			1081·8		
			E 10544	10534			1081·9		
			A 10496	10503			1083·4		
			G 10538	10533	Z 10428	10432	1082·4		
							1082·4	1083·1	4
126*	+0·4	+ 5	E 10631	10534			1082·2		
			F 10627	10534			1082·6		
			G 10621	10533			1083·0		
			H 10623	10585	C 10567	10470	1083·0		
							1082·7	1082·5	4
					Weighted Mean		1082·2°	1082·2°	
					Copper Point—Cont. (Higher Pressure. $p_0=346–347^{mm}$)				
60	−0·7	− 8	A 10500	10502			1083·4°		
			D 10465	10470	Z 10422	10432	1083·6		
							1083·5	1084·1°	1
65	−0·8	− 9	A 10502	10503			1083·0		
			D 10465	10471	Z 10420	10432	1083·4		
							1083·2	1083·9	2
70	−0·3	− 4	A 10508	10504			1082·4		
			D 10475	10472	Z 10444	10432	1082·6		
							1082·5	1081·8	2
78	−0·1	− 1	A 10502	10503			1081·4		
			E 10528	10534			1081·8		
			F 10509	10534			1083·4		
			G 10522	10533	Z 10404	10432	1082·3		
							1082·2	1083·7	4
83	+0·1	+ 1	F 10535	10534			1082·1		
			E 10535	10534			1082·1		
			A 10488	10503			1083·5		
			G 10527	10533	Z 10403	10432	1082·7		
							1082·6	1084·6	4

* Made with outside-wound furnace. See page 106.

Table VIII—(*Continued*)

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Deg'rs	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	

Copper Point—Cont. (*Higher Pressure*)

Exp. No.	Deg'rs	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	Weight
84	+0·7	+ 8	F 10544	10534			1082·0°		
			E 10542	10534			1082·3		
			A 10493	10503			1083·8		4
			G 10533	10533	Z 10426	10432	1083·0		
							1082·8	1083·5	
					Weighted Mean,		1082·7°	1083·7°	
					Mean of 2 pressures,		1082·5°	1082·9°	

Diopside Point. 1391·2°

Exp. No.	Deg'rs	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	Weight
96	0·0	0	E 14227	14228			1392·1°		
			F 14222	14229			1392·5		
			G 14245	14229			1390·7		
			H 14251	14231	Z 14121	14103	1390·4		
							1391·4	1390·5°	1
97	+1·0	+13	E 14260	14228			1392·4		
			F 14254	14229			1393·0		
			G 14287	14229			1390·4		
			H 14295	14231	Z 14156	14103	1389·9		
							1391·4	1390·5	1
99	−0·1	− 1	E 14213	14228			1394·5		
			F 14195	14229			1396·0		
			G 14215	14229			1394·4		
			H 14212	14231	Z 14099	14103	1394·8		
							1394·9	1393·7	1
100	+0·7	+ 9	E 14251	14228			1394·4		
			F 14244	14229			1395·0		
			G 14268	14229			1393·1		
			H 14273	14231	Z 14156	14103	1392·9		
							1393·8	1391·8	1
103	−0·4	− 5	E 14211	14228			1392·5		
			F 14204	14229			1393·1		
			G 14217	14229			1392·1		
			H 14230	14231	Z 14124	14103	1391·2		
							1392·2	1389·4	3
104	+1·0	+13	E 14242	14228			1392·5		
			F 14212	14229			1394·9		
			G 14249	14229			1392·0		
			H 14262	14231	Z 14155	14103	1391·1		
							1392·6	1389·3	3

TABLE VIII—(*Continued*)

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Degr's	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Outside Element	By Inside Element	
				Diopside Point—(Cont.)					
106	−0·6	− 8	E 14228	14228			1391·7°		
			F 14225	14229			1392·0		
			G 14233	14229			1391·3		
			H 14243	14231	Z 14123	14103	1390·7	1390·0°	2
							1391·4		
107	+0·9	+12	E 14248	14228			1391·9		
			F 14237	14229			1392·8		
			G 14245	14229			1392·2		
			H 14252	14231	Z 14152	14103	1391·8	1389·4	2
							1392·2		
130	−0·6	− 7	E 14243	14228			1390·2		
			F 14241	14230			1390·6		
			G 14249	14230			1389·9		
			H 14239	14228	C 14146	14153	1390·6		
							1390·3	1392·0	3
					Weighted Mean,		1392·0°	1390·4°	
				Nickel Point. 1452·3°					
109	+0·7	+ 8	E 15028	14977			1451·2°		
			H 15027	14980	Z 14903	14850	1451·6		
							1451·4	1451·1°	1
111	0	0	E 14980	14977			1453·2		
			H 14978	14980	Z 14867	14850	1453·7		
							1453·5	1452·1	2
112	+0·9	+11	E 14971	14977			1453·8		
			F 14958	14978			1454·9		
			H 14991	14980	Z 14872	14850	1452·4		
							1453·7	1451·5	2
123	−0·6	− 7	E 14984	14977			1454·3		
			F 14989	14978	A 14982	14945	1453·9		
							1454·1	1451·8	2
124	+0·8	+10	E 14989	14977			1454·6		
			F 14994	14978	A 14996	14945	1454·3		
							1454·5	1451·5	1
133	−0·3	− 4	E 14954	14977			1451·9		
			F 14958	14976			1451·5		
			G 14955	14981			1452·2		
			H 14946	14977	C 14882	14898	1452·5		
							1452·0°	1451·3°	4
					Weighted Mean,		1453·0°	1451·6°	

TABLE VIII—(*Continued*)

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Degr's	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Inside Element	By Outside Element	
Cobalt Point. 1489·8°									
115	+0·1	+ 1	E 15390	15439			1488·7°		
			F 15375	15435	A 15357	15409	1489·6		
							1489·1	1488·9°	3
116	+1·4	+17	E 15428	15439			1490·5		
			F 15434	15435			1489·7		
			G 15435	15441	A 15421	15409	1490·1		
							1490·1	1488·6	3
118	−0·5	− 6	E 15385	15439			1491·7		
			F 15383	15435			1491·6		
			G 15393	15441	A 15382	15409	1491·3		
							1491·5	1489·6	2
120	−0·4	− 5	E 15381	15439			1491·7		
			F 15371	15435			1492·1		
			G 15363	15441	A 15379	15409	1493·3		
							1492·7	1489·4	1
121	+0·7	+ 9	E 15406	15439			1492·0		
			F 15405	15435			1491·8		
			G 15398	15441	A 15412	15409	1492·8		
							1492·2	1489·1	1
							1490·6°	1489·0°	
Palladium Point. 1549·2°									
134	−0·7	— 9	E 16151	16143			1549·5°		
			F 16161	16138			1548·3		
			G 16139	16145			1550·6		
			H 16147	16145	C 16075	16058	1550·1		
							1549·6°	1548·8°	
Anorthite Point. 1549·5°									
134	−0·7	— 9	E 16151	16148			1549·9°		
			F 16161	16141			1548·6		
			G 16139	16148			1550·9		
			H 16147	16145	C 16075	16060	1550·0		
							1549·9°	1549·0°	
Interpolation Points.									
49	−0·1	— 1	A 2486	2492			320·2°		
			D 2482	2486	Z 2462	2465	320·0		
							320·1	319·9°	
					Mean for cadmium,		320·0°		
51	0·0	0	A 4451	4450			524·6		
			D 4439	4442	Z 4413	4417	525·0		
							524·8	525·1	
					Mean for A = 4450,		524·9°		

TABLE VIII—(*Concluded*)

Exp. No.	Integrated correction to outside elements		Standard Elements				Temperature		Weight
	Degr's	M.V.	Outside Corrected	Fixed Pt.	Inside Uncorrected	Fixed Pt.	By Inside Element	By Outside Element	
				Interpolation Points—(Cont.).					
62	0·0	0	A 7895	7900			854·2°		
			D 7869	7881	Z 7829	7848	854·9		
							854·6	855·5°	
67	−0·2	−2	A 7883	7900			854·0		
			D 7859	7881	Z 7820	7848	854·5		
							854·3	855·0	
				Mean for A = 7900,			854·7°		
128	−0·2	− 2	E 12004	12000			1206·3		
			F 12001	12001			1206·7		
			G 12008	12001			1206·1		
			H 12000	12003	C 11914	11928	1206 9		
							1206·5	1207·8	
132	+0·1	+ 1	E 11947	12000			1206·0		
			F 11952	11097			1205 3		
			G 11950	12001			1205·8		
			H 11941	12003	C 11887	11928	1206·8		
							1206·0	1205·0	
				Mean for E = 12000,			1206·4°		
129	−0·6	− 5	E 13107	13100			1297·4		
			F 13102	13101			1297·9		
			G 13110	13101			1297·2		
			H 13101	13103	C 13007	13028	1298·1		
							1297·7	1299·3	
				Mean for E = 13100,			1298·5°		

(*Continued from p. 140.*)

If the investigator's responsibility could be made to end with the representation of his own observations, no serious difficulty would arise, but such a formula when published is placed in the hands of many who do not realize that no physical significance was attached to the formula by its author and that its extrapolation in either direction would be fraught with grave danger. A mere inspection of the equation is sufficient to show that the electromotive force does not become zero for zero temperature, thereby immediately proving that extrapolation downward does not correspond to the observed readings of the thermoelement. In the Reichsanstalt equation this constant term was in fact sufficiently large to lead to absurdities if the extrapolation was continued far below 300°.

Notwithstanding the warning contained in this situation, extrapolation upward of the thermoelectric curve has been employed almost universally for the determination of temperatures above 1100°, not only for direct determinations of temperature with the thermoelement itself, but also for the calibration of optical pyrometric apparatus. The absence of absolute determinations in this region has left this practice in undisturbed security until recently, when some doubt has been thrown upon the validity of irresponsible upward extrapolation by various observations. (1) The increase in the accuracy now attainable with the optical pyrometer has given an independent thermal scale comparable with that of the thermoelement and overlapping the same region. The two curves have not been found to correspond. (2) Experimental determinations of the melting point of platinum by continuing observations of the thermoelement up to a point where a portion of its platinum wire melts, have been undertaken in the national laboratories of Germany, England and the United States, and have yielded a value measured upon the extrapolated thermoelectric curve of about 1710°. The agreement in the different determinations was good and the result found general acceptance for a time. More recently, Holborn and Valentiner have made successful measurements with the gas thermometer at the temperature of melting palladium, and although high accuracy was not attempted, it became clear that the palladium point obtained by extrapolating with the thermoelement was much too low and by inference the platinum point also, for the various optical methods give opportunity for a very good determination of the temperature difference between the melting points of the two metals. The most recent estimates of the platinum melting point obtained in this way place it between 1750° and 1775°, indicating that the upward extrapolation with the thermoelement has given rise to an error of about 50° at the platinum point.

The data obtained in the present investigation throw much light upon this situation. If we take the observations of our series over the range covered by the Reichsanstalt scale (300° to 1100°) and write an equation for these of the same type as that used at the Reichsanstalt, it will read,

$$E = -302 + 8{\cdot}2356t + {\cdot}0016393t^2$$

and this equation will reproduce the temperatures of the standard melting points which fall in this region with a maximum error of 3 microvolts, an accuracy far within the errors of observation. But if we extrapolate this curve in accordance with the general practice above described, and compare the resulting electromotive forces with our observations between 1100° and

1550°, a somewhat startling surprise awaits us. Although the curve below the copper point is a practically perfect reproduction of the observations, it diverges from the gas thermometer scale at the melting point of palladium by 245 microvolts, which represents a temperature error of nearly 20°. This comparison is made in the table below :

	Temperature	Observed Microvolts	Calculated Microvolts	Observed—Calculated Microvolts
Zinc	418·2°	3429	3429	0
Antimony ...	629·2	5530	5530	0
Silver	960·0	9113	9115	—2
Gold	1062·4	10295	10298	—3
Copper	1082·6	10534	10534	0
		Extrapolation.		
	1207·1	12000	12027	—27
	1298·8	13100	13161	—61
Diopside	1391·2	14228	14338	—110
Nickel	1452·3	14945	15112	—167
Cobalt	1489·8	15439	15608	—169
Palladium ...	1549·2	16143	16388	—245

If, on the other hand, we follow Day and Clement, and represent t as a function of E, using the same data as before, the equation will take the form

$$t = 47{\cdot}2 + {\cdot}11297E - 1{\cdot}3946(10)^{-6}E^2$$

This curve passes through the fixed points below 1100° nearly as accurately as the previous one, and is also quite competent to interpolate temperatures throughout the range of the old standard scale. Extrapolating this in turn up to the palladium point and comparing it with our gas thermometer measurements in the higher region leads to temperatures about 40° too low.

	Observed	Calculated	Observed—Calculated
Zinc	418·2°	418·2°	0°
Antimony ...	629·2	629·3	—0·1
Silver	960·0	960·9	—0·9
Gold	1062·4	1062·4	0
Copper	1082·6	1082·5	+0·1
	Extrapolation		
	1207·1	1202·0	+5·1
	1298·8	1287·8	+11·0
Diopside	1391·2	1372·0	+19·2
Nickel	1452·3	1424·0	+28·3
Cobalt	1489·8	1459·0	+30·8
Palladium ...	1549·2	1507·0	+42·2

The untrustworthiness of the present practice of extending thermoelement values obtained below 1100° into the region above that temperature is therefore abundantly demonstrated.*

We were unable to find a simple parabola with which to represent the whole series of observations between 300° and 1550° within the errors of observation. The simplest procedure is therefore to divide the long curve into two parts. This plan is carried out below in the form in which it will probably be found most useful. A parabola passing through zinc, antimony and copper reproduces the results over that temperature range within the errors of observation. A similar parabola through copper, diopside and palladium gives the upper temperatures as accurately as they were measured. These two equations offer a means of safe and convenient interpolation throughout the entire range of the gas thermometer measurements. In this series are included certain gas thermometer measurements given at the end of Table VIII which were made at temperatures between the fixed melting points, for the purpose of checking the interpolation formula, together with a single gas thermometer determination of the cadmium melting point. The temperature 854·1 appears here corrected by −0·6°, since the series, of which this measurement formed a part, showed a systematic difference of about this amount from the final average of antimony and silver, which lie on either side of this point.

Cadmium to Copper

$$E = -302 + 8{\cdot}2356t + {\cdot}0016393t^2$$

	Temperature	Observed Microvolts	Calculated Microvolts	Observed—Calculated Microvolts
Cadmium	320·0°	2504	2501	+3
Zinc	418·2	3429	3429	0
	524·9	4470	4472	−2
Antimony	629·2	5530	5530	0
	854·1	7927	7928	−1
Silver	960·0	9113	9115	−2
Gold	1062·4	10295	10298	−3
Copper	1082·6	10534	10534	0

Copper to Palladium

$$E = -1941 + 11{\cdot}1746t + {\cdot}00032161t^2$$

	Temperature	Observed Microvolts	Calculated Microvolts	Observed—Calculated Microvolts
Copper	1082·6	10534	10534	0
	1207·1	12000	12010	−10
	1298·8	13100	13112	−12
Diopside	1391·2	14228	14228	0
Nickel	1452·3	14977	14967	+10
Cobalt	1489·8	15439	15421	+18
Palladium	1549·2	16143	16143	0

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* For an account of some of the dangers of careless interpolation, see Day and Clement, loc. cit., p. 453.

It is possible to write a cubic equation which will reproduce the entire series from zinc to palladium without error greater than the normal accuracy of the observations themselves. The equation offered makes no pretensions to a least square solution with balanced residuals, but is arranged so that the greatest uncertainties are found in that portion of the curve where the greatest experimental error lies. The coefficients were rounded off for convenience of computation.

Cadmium to Palladium

$$E = -169{\cdot} + 7{\cdot}57t + 0{\cdot}002648t^2 - 0{\cdot}0000004724t^3$$

	Temperature	Observed Microvolts	Calculated Microvolts	Observed—Calculated Microvolts
Cadmium	320·0°	2504	2509	−5
Zinc	418·2	3429	3425	+4
	524·9	4470	4466	+4
Antimony	629·2	5530	5525	+5
	854·1	7929	7934	−5
Silver	960·0	9113	9121	−8
Gold	1062·4	10295	10296	−1
Copper	1082·6	10534	10530	+4
	1206·4	12000	11988	+12
	1298·5	13100	13091	+9
Diopside	1391·2	14228	14215	+13
Nickel	1452·3	14977	14963	+14
Cobalt	1489·8	15439	15424	+15
Palladium	1549·2	16143	16157	−14

6. *Analysis of Metals.* (*By E. T. Allen.*)

The object of these analyses was primarily, of course, to decide whether the metals should be used or rejected for the temperature scale, and those selected were examined very carefully so that in the future, when more is known about the specific lowering which the various impurities produce on the melting point, corrections may be made if desirable.

The accuracy of the determinations is problematical. There is of course the possibility of increased solubility of difficultly soluble compounds in the comparatively concentrated solutions of the metals from which the impurities have to be precipitated, viz., 5 to 6 g. in 250^{cc} volume. Also, when it is necessary to separate the bulk of the metal by precipitation from the impurities, as it sometimes is, one cannot be sure that the impurity sought is not occluded by the precipitates. In most cases, the latter source of error is probably the more serious. Only methods worked out synthetically with materials laboriously prepared could decide these questions. Large quantities of metal, 25 to 100 g., were generally taken for analysis, and since the impurities were weighed to the tenth of a milligram, the results are generally stated to the ten-thousandth of a per cent. This does not mean that the results are considered accurate to this figure. The variation in successive determinations comes in the thousandths, so that the fourth decimal place may have about as much value as the second in an ordinary analysis. Great pains have been taken to purify precipitates, often by many precipitations, so that in all cases the figures given may be regarded as minima. In all cases, too, I have endeavored to avoid missing anything, by repeating every process, rejecting no precipitate or solution until it was decided that nothing more was to be gotten from it. In any reasonable case of suspicion, blank determinations were made with the reagents.*

Heraeus' Palladium.

The palladium was naturally suspected to contain other metals of the platinum group. It is well known that the separation of these metals is a problem of unusual difficulty. The plan here was therefore to precipitate most of the palladium from solution as one of its characteristic compounds and, while the filtrate was reserved for impurities, to redissolve and again precipitate the metal as another characteristic compound. In this way it was hoped that those impurities which were retained by the first precipitate would not be occluded by the second. The sheet metal was first cut into shavings on a milling machine which was especially cleaned for the purpose. Then the shavings were boiled a short time with dilute hydrochloric acid to remove any iron from the surface, washed and dried. After an unsuccessful endeavor to dissolve the palladium in nitric acid (insoluble brown hydroxide (?) always formed), it was dissolved in aqua regia and rid of nitric acid by successive evaporations with excess of hydrochloric acid. It was then dissolved in dilute hydrochloric acid and diluted further to about 1 l. Ammonia was added in excess.† A precipitate came down and redissolved on warming—all but a little ferric hydroxide which was filtered off. The filtrate was then evaporated again to about 250^{cc}, diluted and precipitated with stirring, by dilute hydrochloric acid. The voluminous precipitate of $PdCl_2.2NH_3$ was now filtered and washed on a Büchner porcelain funnel, using suction. The filtrate we will call "solution A." The precipitate was then dried and ignited in a large porcelain crucible. The resulting metal was dissolved in aqua regia and freed of nitric acid. This solution was diluted and precipitated by potassium iodide, and the filtrate—"solution B"—removed as above.

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* After considerable experience in the examination of these "pure" metals, the writer has reached the conclusion that a 10 g. portion, in the great majority of cases, will give as satisfactory results as a larger portion and with far less labor.

† E. F. Smith and H. F. Keller, Amer. Chem. Jour., xiv, 423, 1892.

From solutions A and B, separately, the platinum metals were first removed by long boiling with ammonium formate. The metal—1 to 2 g. in weight, mostly palladium—was filtered and the filtrate and washings were examined further for other heavy metals by the usual methods.

Separation of the Palladium from the Platinum Metals.—Considering now the ammonium formate precipitate, Erdmann and Makowka* have obtained satisfactory separations of palladium from platinum and iridium by treating the solution of the mixed chlorides with acetylene. Palladium comes down as acetylide and the other metals are unprecipitated. I found also that *rhodium* solutions even on heating were not precipitated by acetylene. As for osmium, the ease with which it oxidizes and the high volatility of its oxide makes its elimination, in the process of preparing the palladium, fairly certain. Ruthenium, the rarest element among the platinum metals, need hardly be looked for; still it was sought for in the iridium found. The acetylene method was used, for lack of a safer one, though very tedious. In solutions at all concentrated, I find the palladium ceases to precipitate long before it is entirely removed from solution. Perhaps this is due to the accumulation of acid liberated in the process. At least, when the solution is separated from the acetylide, evaporated and diluted again, acetylene brings down another portion. After five or six operations, a residual solution was obtained on which acetylene had no further action. The acetylide was now carefully ignited with a little ammonium nitrate, the metal redissolved, and the whole process repeated. The residual solution was then added to the first and from it NH_4Cl brought down platinum. In the chlor-platinate no iridium was found. It was ignited and the metal was entirely soluble in a few drops of aqua regia. It was again precipitated with NH_4Cl and finally weighed as platinum—Pt = 1·6 mg. = 0·007 per cent. No rhodium was found in the filtrate. In the attempt to dissolve in aqua regia the several portions of metal formed by igniting the acetylide, tiny insoluble residues accumulated. These were fused with $KHSO_4$, which, as is well known, dissolves palladium and rhodium but not iridium or platinum if the temperature is kept low. The soluble portion was dissolved in water and precipitated with ammonium formate. It turned out to be palladium, since it was precipitated by potassium iodide and no trace of rhodium was found.

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* Zeitschr. anal. Chemie, xlvi, 146, 147, 1907.

The portion insoluble in $KHSO_4$ was freed from silica (which came from the dish) by HCl+HF, ignited, and weighed. Ir + [Ru] = 1·9 mg. = 0·008 per cent. When fused with $K_2CO_3 + KNO_3$, some blue insoluble IrO_2 was formed, but the fusion showed no yellow color, and in view of the minute quantity of material, it was not thought worth while to search more carefully for ruthenium.

The final precipitate of palladium acetylide was changed to chloride, diluted, and saturated with SO_2 for gold, but none appeared.

Nothing else was found in the metal except a trace of copper. The iron found earlier had to be reprecipitated several times from chloride solution by ammonia to get rid of palladium. The precipitate was finally transformed into sulphate and determined volumetrically.—Fe = 2·6 mg. = ·010 per cent.

Analysis of Palladium.

Au	none
Ru	none
Rh	none
Pt	·007%
Ir	·008%
Cu	trace
Zn .... doubtful	trace
Fe	·010%
	·025%

Kahlbaum's Electrolytic Nickel.

Two 50 gram portions were dissolved separately in measured quantities of nitric acid and then carried to white fumes with excess of sulphuric acid. Both portions were then dissolved in water and filtered. There was a small dark residue which was washed thoroughly and extracted with aqua regia, leaving a little silica from the dish. The yellow chloride obtained was freed from nitric acid, saturated with SO_2 and left to stand. *No gold.* Changed to chloride again and tested with caustic soda and H_2O_2. *Still no gold.* Acidified and reprecipitated with NH_4Cl, a characteristic yellow precipitate was obtained. Confirmed by dissolving the chlor-platinate in hot water and precipitating by hydrogen. Pt = 2·3 mg. = 0·0023 per cent. The main solution was then precipitated by H_2S (v = 2 l.). The small black precipitate obtained was worked over for gold and platinum with the above.

Other heavy metals were tested for in the ordinary way. 0·2 mg. $PbSO_4$ = about 0·1 mg. Pb. Cu = 52·3 mg. = 0·0523 per cent.

Ammonium Sulphide Group.—The voluminous solution was now freed from hydrogen sulphide by evaporation, some ammonium persulphate was added and a stream of air passed through the solution for some time. *No manganese.* $Fe_2O_3 = 6{\cdot}1$ mg., after repeated precipitation. Fe = 4·2 mg. Repeated efforts were made to separate zinc with H_2S on the principle of the lower solubility of ZnS in dilute acids, but without satisfaction. First I tried to precipitate a small fraction of the nickel, hoping to get all the zinc with it. The volume of the solution was about 5 l. But unless so much acid was added that strong doubts were entertained of recovering any zinc that might be present, the fraction of the nickel precipitate was far too great. Again, all the nickel was precipitated and the precipitate was digested with cold 10 per cent solution of hydrochloric acid. Here one had to fear either the failure to remove the zinc or the removal of too much nickel to handle without so many precipitations that a small quantity of zinc would probably be lost. It is doubtful whether we have any method which will give very small amounts of zinc in metallic nickel.

The whole solution was now tested for cobalt as follows: It was freed from H_2S by evaporation, acidulated with HCl and precipitated by α-nitroso-β-naphthol in 50 per cent acetic acid. This was added in several portions. After long standing the precipitate was collected and washed. The voluminous precipitate was very cautiously burned in a capacious porcelain crucible. Much tar was formed. The residual oxide was dissolved in nitric acid and the cobalt separated from nickel by KNO_2 in the usual way. The potassium cobalto-nitrite was finally decomposed by sulphuric acid and precipitated electrolytically from ammoniacal solution. Co = 101·4 mg. + 4·9 mg. recovered from filtrate and weighed as sulphate. Total = 0·1063 per cent. Fe and Co were also determined in a separate 10 g. portion of metal. $Fe_2O_3 = 0{\cdot}7$ mg. Fe = 0·49 mg. = 0·0049 per cent. Co = 10·3 mg. = 0·1030 per cent. A separate 10 g. portion was taken for sulphur. It was dissolved in nitric and evaporated on the water bath. This solution was diluted and precipitated with a slight excess of sodium carbonate. The filtrate was just acidulated, evaporated, and treated with barium chloride. No precipitate.

Analysis of Nickel.

Au	none	Bi	none
Pt	·0023%	Cd	"
As	none	Zn	none found
Sb	"	Co	·1063%
Sn	"	Mn	none
Pb	·0001%	Fe	·0042%
Cu	·0523%	S	none
			·165%

Kahlbaum's Cobalt.

Two 25 g. portions of the metal in the form of powder were dissolved in 150^{cc} water+35^{cc} concentrated H_2SO_4. The analysis was quite similar to that of the nickel. In the H_2S group were found: Cu=8·9 mg.=0·0178 per cent. $PbSO_4$= 12·9 mg. Pb = ·0176 per cent. In the $(NH_4)_2S$ group manganese was tested for as in the nickel. None was found. Fe_2O_3 = 0·9 mg. Fe = ·0006 per cent. As the tests for Ni and Zn were unsatisfactory, another portion of 25 g. was dissolved in dilute sulphuric acid and precipitated by H_2S. The filtrate from the sulphides was filtered and freed from excess of H_2S by evaporation. Then it was diluted to 1 liter and divided into two portions. Both were neutralized by sodium carbonate. In the one, manganese was sought for by ammonium persulphate. In the other nickel was looked for. A little ammonia was added and then an alcoholic solution of dimethylglyoxime. A precipitate containing much cobalt was obtained. This was worked over for nickel but none was found. For sulphur the method used in the analysis of nickel was followed. $BaSO_4$ = 14·4 mg., blank = 5·1 mg., difference = 9·3 mg., S = 0·013 per cent.

Analysis of Cobalt.

Ag	none	Cu	·0178%
Au	"	Bi	none
Pt	"	Cd	"
As	"	Zn	"
Sb	"	Ni	"
Sn	"	Fe	·0006%
Pb	·0176%	Mn	none
		S	·013%
			·049%

Aluminum.

Owing to the difficulty of handling this metal, small portions (10 g.) only were taken for analysis. *Heavy metals*, except arsenic and antimony, were sought for in the hydrochloric acid solution by ordinary methods. Only a trace of copper was found.

Phosphorus, Arsenic, and Sulphur.—For these elements, a separate portion was dissolved in caustic alkali in a special apparatus entirely of glass. The vessel was first filled with purified hydrogen and then the alkali was introduced and the gases evolved were passed through silver nitrate solution. At the end, the gases remaining in the vessel were displaced by hydrogen. The precipitated silver was worked over for the different elements. *No As nor Sb.* A separate portion was used for sulphur. $BaSO_4$ = 1·4 mg. S = ·002 per cent.

Silicon.—10 g. metal were dissolved in a mixture of nitric and sulphuric acids, using a platinum dish. With hydrochloric acid alone nearly all the silicon is lost as hydride. The brown amorphous residue was filtered, washed and fused with sodium carbonate. From the fusion silica was obtained in the usual way. SiO_2=41·4 mg. Si=0·194 per cent. Repetitions gave 0·189 per cent and 0·190 per cent.

Carbon.—10 g. metal were dissolved in NaOH and filtered through glowed asbestos, washed first with water, then with dilute acid and finally with water and dried at 105°. The asbestos and residue were then transferred to a combustion tube and burned in air free from CO_2. The gases were passed through standard $Ba(OH)_2$. A considerable precipitate was obtained, while a blank gave no trace. The excess of $Ba(OH)_2$ was the ntitrated with standard acid using phenolphthalein as indicator. 5·05 mg. CO_2 found. C = 0·014 per cent. A duplicate in which the metal was dissolved in KOH gave 0·012 per cent.

Iron.—10 g. metal were dissolved in hydrochloric acid, and to the solution was added tartaric acid free from iron. From this solution the iron was precipitated by colorless ammonium sulphide. The precipitate was finally changed to sulphate and determined volumetrically. Fe = 4·6 mg. Blank determination gave 0·3 mg. Fe = 0·043 per cent.

Calcium, Sodium, and Potassium were sought for in the hydrochloric acid solution, by precipitating with ammonia, washing the large precipitate and testing the evaporated filtrate. *No Ca.* Some alkaline chloride was found, but a blank showed that it came from the ammonia, as there was only a difference of 1·6 mg. between the chloride of the blank and that in the determination. *No Na or K.*

Analysis of Aluminum.

As	none	C	0·013%
Sb	“	S	0·002%
P	“	Ca	none
Cu	0·003%	Na	“
Fe	0·043%	K	“
Si	0·190%		
			0·251%

Antimony.

25 g. metal were powdered in an agate mortar and treated with 35 per cent HNO_3 on the steam bath. As soon as the reaction was practically complete, the antimonic acid was extracted

with hot dilute nitric acid, transferred to a filter and washed with water. The filtrate and washings were then evaporated to dryness with hydrochloric acid, while the antimonic acid was digested repeatedly with yellow sodium sulphide till the soluble portion was dissolved. The residue, after a little washing, was dissolved in nitric acid, evaporated to dryness, freed from nitric by hydrochloric acid, and the chlorides united with the first extract. The whole was precipitated by hydrogen sulphide. The washed sulphides were then extracted with colorless ammonium sulphide. From this solution the sulphides were thrown down by acid, filtered and washed. Then they were dissolved in hot dilute caustic potash. The solution was boiled with perhydrol for complete oxidation, and arsenic sought for by Fischer's method, viz., reducing by ferrous ammonium sulphate and distilling in a current of hydrochloric acid gas. *No As.*

A separate portion of 5 g. was taken for tin. McCay's method was tried.* $SnO_2 = 1·3$ mg. $Sn = 1·0$ mg. $= ·02$ per cent.

A separate portion of 25 g. was used for sulphur. The metal was oxidized by nitric acid as before, and the soluble portion separated and evaporated. The residue was then heated with a small excess of sodium carbonate and filtered. The residue was also boiled out several times with sodium carbonate solution. The two solutions were then acidified with hydrochloric acid and treated with barium chloride. The portion soluble in nitric acid gave a slight precipitate, which was further purified, after the usual washing and drying, by fusion with sodium carbonate. The water extract containing the soluble sulphate was acidified and precipitated a second time. $BaSO_4 =$ trace.

Analysis of Antimony.

As	none	Cd	none
Sn	0·02 (?)	Ni	"
Ag	none	Co	"
Pb	trace (?)	Mn	"
Cu	0·004	Zn	"
Bi	none	Fe	0·007%
		S	trace (?)
			·031%

In the following table, the results of these and previous† analyses of metals for the temperature scale are summarized:

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* Private communication.

† Day and Clement, loc. cit., p. 454.

*Summarized Analyses of Metals.**

Impurities stated in fractions of 1%	Metals							
	Palladium	Cobalt	Nickel	Copper	Silver	Aluminum	Antimony	Zinc
Pt	0·007	none	·0023	·0011†	·0001			
Ir	·008							
Rh	none							
Ru	"							
Au	"	none	none	none	·0005			
Se				"				
Te				"				
As		none	none	"	none	none	none	none
Sb		"	"	"	"	"		·002
Sn		"	"	"	"		·02 (?)	
Hg					"		none	
Ag		none	none	·0006			"	none
Pb	none	·0176	·0001	none	·0008			·051
Bi	"	none	none	"	none		none	none
Cu	trace	·0178	·0523		trace	·003	·004	none
Cd	none	none	none	none	none		none	·004
Ni	"	"		"	"	none	"	none
Co	"		·1063	"	"	"	"	"
Fe	·010	·0006	·0042	·0038	·0011	·043	·007	·006
Zn	trace ?	none ?	none ?	·0007	none		none	
Mn		none	none				"	
Si				none		·190		none
C					·0003	·013		
S		·013	none	·0020	·0004	·002		none
P						none		
Ca						"		
Na						"		
K						"		
Total	·025	·049	·165	·008	·003	·251	·031	·063

*** A blank opposite any impurity means that it was not looked for.**
† Means platinum metals.

7. *Conclusion.*

It is now something over five years since the Geophysical Laboratory took up the task of redetermining the absolute temperature scale from 300° to 1100° with the nitrogen thermometer, and of extending it, if it should prove practicable to do so, to 1600° C., for it is in this upper region that most of the mineral relations which it is the chief purpose of the laboratory to study are found. Two preliminary publications have been made during the investigation. One, a brief summary of preliminary work up to 1100°, was given before the National Academy of Sciences and the American Physical Society in April, 1907,* the second covered the same ground at considerable length in 1908.* The present paper extends the observations to 1550°, and completes the work contemplated under the original plan.

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* Abstract, Phys. Rev. xxiv, 531, 1907.

No attempt will be made to offer an inclusive summary of the whole investigation. It is a record of experimental measurements covering an unusually wide range of details which do not admit of brief classification. The errors which have heretofore been present in measurements with the nitrogen thermometer have been reduced by the present investigation to about one-fourth their former magnitude and the certainty of their evaluation is at least proportionately increased.

The chief source of present uncertainty is the temperature distribution over the surface of the bulb in an air bath. No indication of a limit to the temperature attainable with the nitrogen thermometer or to its ultimate accuracy was discovered during the present investigation.

The magnitudes of the errors, and their effects on the temperature, are summarized in Table IV, page 129. The determinations of the expansion coefficient of the bulb material (80 Pt. 20 Rh) are summarized on pp. 131–132.

The melting temperatures of the metals and salts which have been used as fixed points to establish the new scale are brought together in the table below, together with the conditions under which the determinations were made. The generally accepted Reichsanstalt scale is printed beside it for convenient comparison. The analyses of the metals are summarized on p. 159.

To this table has been added a new estimate of the melting temperature of platinum, of which we could make no direct determination. Its general acceptance and availability as a fixed point of reference, and the wide disagreement between the direct determinations heretofore made of it, form a sufficient reason for its inclusion. The estimate is arrived at in this way: There is a remarkably close agreement between independent determinations of the *temperature interval* between the melting points of palladium and platinum:

Nernst and von Wartenberg†	204°
Holborn and Valentiner (at the Reichsanstalt)‡	207°
Waidner and Burgess (at the Bureau of Standards) §	207°

If we therefore simply add 206° to our determination of the palladium point, we obtain 1755° as the melting point of pure platinum, with an absolute error of perhaps no more than ± 5°. The table follows:

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* This Journal (4), xxvi, 405, 1908.

† W. Nernst and H. von Wartenberg, Ber. d. Deutsch. phys. Ges., iv, pp. 48, 146, 1906.

‡ L. Holborn and S. Valentiner, Ann. d. Phys. (4), xxii, 1, 1907.

§ C. W. Waidner and G. K. Burgess, Bull. Bur. Standards, iii, p. 163, 1907.

Substance	Point	Atmosphere	Crucible	Temperature	The Reichsanstalt Scale
Zinc	Melting and freezing	Aii	Graphite	418·2° ±0·3	419·0°
Antimony	Do.	Carbon monoxide	Do.	629·2 ±0·5	630·6
Silver	Do.	Do.	Do.	960·0 ±0·7	961·5
Gold	Do.	Do.	Do.	1062·4 ±0·8	1064·0
Copper	Do.	Do.	Do.	1082·6 ±0·8	1084·1
Diopside (pure)	Melting	Air	Platinum	1391·2 ±1·5	
Nickel	Melting and freezing	Hydrogen and Nitrogen	Magnesia and Magnesium Aluminate	1452·3 ±2·0	
Cobalt	Do.	Do.	Magnesia	1489·8 ±2·0	
Palladium	Do.	Air	Pure Magnesia	1549·2 ±2·0	1575·*
Anorthite (pure)	Melting	Do.	Platinum	1549·5 ±2·0	

In addition, the following temperatures were incidentally obtained:

Cadmium	Melting and freezing	Air	Graphite	320·0 ±0·3	321·7
Aluminum	Freezing	Carbon monoxide	Do.	658·0 ±0·6	657·
Platinum	Melting	Air		1755·	

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., December 24, 1909.

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* Holborn and Valentiner, loc. cit.

ART. IX.—*A New Sclerometer;* by A. L. PARSONS (University of Toronto).

THE physical properties of minerals and metals have for a long time been a subject for investigation, and among the first of these properties to be studied were hardness and tenacity, but although the tensile strength and crushing point of the various substances are easily measured, the determination of hardness or resistance which a substance offers to abrasion is not so well understood. The sclerometer which was devised by Seebeck and later improved by Grailich and Peckarek is the one which is best known, but it is little used because the length of time which is required for a single measurement prevents the common use of an instrument which should be of valuable assistance to the mineralogist and metallurgist.

A bibliography of works on sclerometry is given by Jaggar* which includes the most important papers and outlines the principles employed by various investigators in using their own instruments or those devised by others.

The new instrument differs from those of Seebeck, Grailich and Pekarek and others in that the force that is necessary to make a scratch is measured by means of a spring and not by weights.

Description of the Instrument.†

The instrument consists of four working parts on a base, as follows (see fig. 1):—

1. *Steel spring* (F) with test-point holder (H) fastened to the column (S).
2. *Object holder* (O) with divided horizontal circle (C), horizontal screw (1) for moving the object to be tested from side to side, and two vertical screws (2 and 3) to give the object the desired inclination.
3. Carriage (7) with transport screw (4) and spring (5) to move the test object, while making the scratch, and a slide (6).
4. Micrometer screw (E) and scale (8) to measure the elevation, which is proportionate to the force necessary to make a scratch.
5. Base (G) to hold the working parts together.

1. The spring (F) consists of a strip of steel 120^{mm} long, from the column (S) to the test point, 4–8^{mm} wide and 0·75^{mm} thick. It is firmly fastened by a screw to the top of the column (S) and with this can be raised or lowered in the socket (B). The rod (St) behind the column prevents lateral movement of the spring in raising or lowering the same. On the free end of the spring is screwed the test point holder (H_1, H_2, or H_3) which carries the crystal point or metal point with which the test object is to be scratched.

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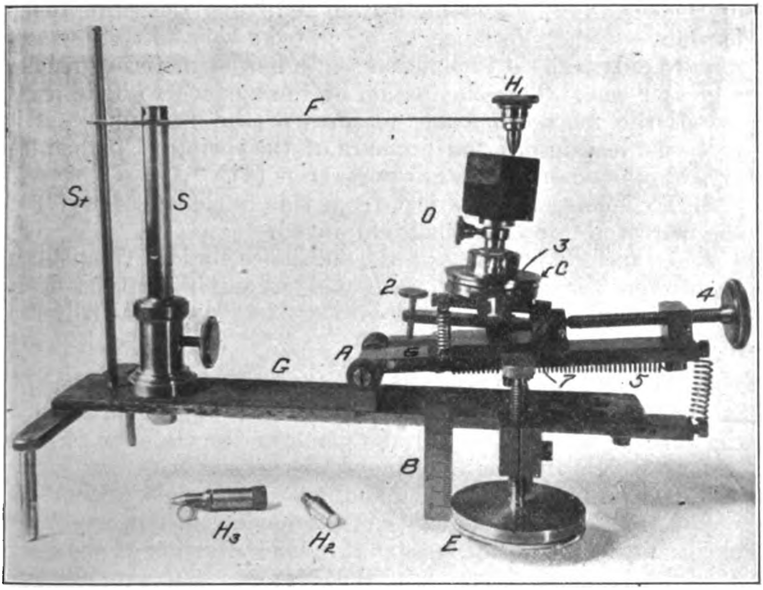
* This Journal (4), iv, p. 399, 1897.

† Price of instrument, 80 marks from the mechanic, P. Stoe, Heidelberg, Germany, Jubilaeums Platz, 70.

The following three point-holders seem desirable and are provided with the instrument: H_1 with diamond point. This is preferably a tetrahedral cleavage fragment, as this form gives the sharpest cutting edge and is least liable to variations in hardness. H_2, a holder in which a needle of steel or other metal can be fastened. Generally a sewing needle is used, as there is little variation in hardness in needles from the same packet. For very soft substances a brass pin or a copper point may be employed. H_3, a holder with a cup-like depression in which a crystal or other substance may be fastened by means of wax "kit."* This may be either a substance of *known* hardness with which another is to be compared or one of *unknown* hardness which is to be tested by scratching the surface of a substance whose hardness is known.

Fig. 1.



* A piece of "kit" is provided with each instrument.

2. The object carrier (O) holds the crystal or other test object firmly in the position desired for making the tests. The crystal is fastened by wax "kit" to a small plate which is set in a socket at the top of the carrier.

The adjustment of the test object is as follows:

1. To bring the surface under the test point the transport screw (4) and the screw (1) are used. The screw (1) has also the purpose of moving the test object from side to side so that duplicate measurements may be made in parallel positions.
2. To give the face of the test object the desired inclination so that it forms with the slide (6) a wedge, it is tilted by means of the screw (2). The inclination will vary according to the hardness of the substance to be tested; very soft substances require only a slight inclination while harder materials require a greater one. This inclination of the surface to be tested is one of the most important features of the instrument, as it gives the measure of the pressure of the spring (F) when the crystal is moved by the transport screw (4).
3. To level the test object from side to side a screw (3) on the rear of the instrument is employed.
4. To test the hardness of the substance under investigation in different directions the graduated circle (C) is turned about its axis. This circle is divided into 36 parts so that each division gives 10°.

3. The transport screw (4) and accompanying spring (5) move the test object under the test point. The inclination of the surface to be tested to the plane of the slide (6) forms a wedge which by the movement of the screw (4) raises the spring (F) until a scratch is made.

4. The micrometer screw (E) raises or lowers the test object until it just touches the test point. Each division on the screw head measures an elevation of $0{\cdot}01^{mm}$.

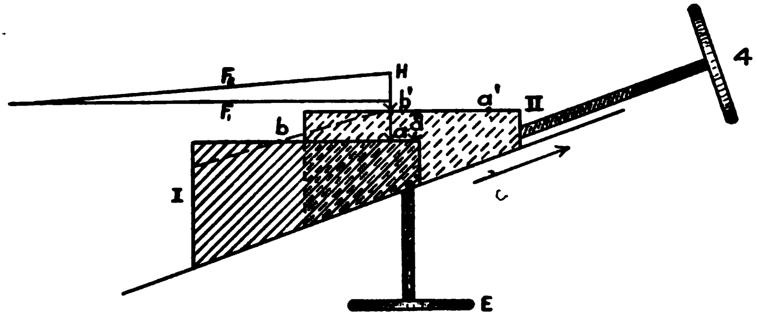
5. The base (G) carries the different parts and needs no particular description.

Measurement.

The crystal or other test object is fastened to the top of the object holder (O) and inclined by means of the screw (2) so that the face to be investigated forms a wedge with the track (6). By the screw (3) it is made horizontal from side to side. By raising or lowering the column (S) the test point is brought to a position where it nearly touches the surface to be tested. By means of the micrometer screw the crystal is then raised until the test point just comes in contact with the face to be tested at the point *a*, fig 2.

Now by means of the transport screw (4) and the accompanying spring (5) the crystal is moved in the direction indicated by the arrow points so that as the surface acts as a wedge the test point (H) is raised and the spring (F) is bent from position F_1 to position F_2. By this movement a position is reached where the test point makes a scratch on the surface to be tested which is indicated in the figure as *b*. By the movement of the test object from position I to position II this point *b* has been brought to the position *b'* and the point *b* has also been raised the distance *a b'* = *d*. After the scratch has been made a reading is made on the micrometer screw E. The crystal is then lowered by means of the micrometer screw until the test point just touches the crystal or other substance at the point *b'*, in other words at the beginning of the scratch, and a second reading is made on the micrometer screw which gives the distance *ab'* in divisions on the micrometer screw. This distance gives a measure of the bending of the spring or of the pressure necessary to make a scratch on the crystal, that is, it is a measure of the hardness.

Fig. 2.



In practice the lowering of the crystal by means of the micrometer screw gives a forward motion of the crystal in the direction of the arrow points in the figure and the beginning of the scratch must be brought under the test point by the transport screw (4). It is also found better in practice to lower the crystal or other test object so that the test point does not touch the surface, and then raise the test object again until the point just touches.

Calibration.

In this instrument the force that is necessary to make a scratch is measured by the strain on the spring (F) and the reading is made in divisions on the micrometer screw (E). In the instruments of Seebeck and others this same force is measured by the weights with which the test point is loaded. This measurement by weights has the advantage that the weights are constant, while the bending of the spring (F) is dependent upon the material and dimensions of the same, and with each instrument we get a different factor. In order to reach comparable results it is necessary to reduce the divisions on the micrometer screw to measures of weight This reduction of elevation to weight is called the *calibration of the instrument.**

The calibration of the instrument is made in this way. A glass plate is fastened to the object carrier and a scratch is made with the diamond point. The glass is now brought to the position where the test point just touches the beginning of the scratch. This point is determined when the test point just meets its reflection in the glass. The reading on the micrometer screw (E) is taken, the plate lowered by means of the micrometer screw and a weight placed on the test point holder (H) by which the spring is bent. The plate of glass is now raised until the test point just touches the beginning of the scratch and a second reading is made on the micrometer screw (E). Subtracting the second reading from the first gives the number of divisions on the micrometer screw that corresponds to a given weight.

By lowering the glass plate by means of the micrometer screws not only the plate but the track (6) and the object carrier (O) describe a small arc of a circle about A so that the beginning of the scratch must be brought under the point by means of the transport screw (4).†

The deflection of the spring for various weights is measured and a table can be made for all.

The results of the calibration are as follows:

	Weight grm.	Reading	Deflection of needle in divisions of graduated circle	No. of divisions equivalent to 1 grm.	Mean No. of divisions equivalent to 1 grm.
First trial..	0	183·0	0		
	5	170·0	13	2·6	
	10	159·0	24	2·4	
	20	134·5	48·5	2·425	
	50	60·5	122·5	2·45	2·469

---

* Every instrument is furnished with a calibration table so as to give the weight that corresponds to one division on the micrometer screw.

† A very slight error is thus introduced but in practice this can be neglected, as the determinations of hardness are made in the same way and the errors are comparable.

	Weight grm.	Reading	Deflection of needle in divisions of graduated circle	No. of divisions equivalent to 1 grm.	Mean No. of divisions equivalent to 1 grm.
Second trial.	0	211·5	0		
	5	199·0	12·5	2·5	
	10	186·5	25·0	2·5	
	20	162·5	49·0	2·48	
	50	86·0	125·5	2·51	2·4975
Third trial..	0	135·0	0		
	5	123·0	12·0	2·4	
	10	110·0	25·0	2·5	
	20	85·0	50·0	2·5	
	50	7·0	128·0	2·56	2·49
Fourth trial.	0	193·5	0		
	5	180·5	13·0	2·6	
	10	168·5	25·0	2·5	
	20	143·5	50·0	2·5	
	50	67·0	126·5	2·53	2·5325
Mean of all					2·4975

The results agree closely so that the elevation may be considered proportional to the weight and in this instrument a load of 10 grams is equivalent to 25 divisions on the micrometer screw.

Results of Measurements.

Plane and polished surfaces of glass, iron, copper, and brass were taken as test objects. A few trials were made with crystal faces, but further study is necessary before it can be stated that the instrument is suitable for determining the hardness of unpolished surfaces.

Measurements with the diamond point (a tetrahedral cleavage fragment):

A. *Copper.* 10 measurements: Pressure = 1·2, 1·2, 1·8, 1·6, 1·6, 1·4, 1·6, 1·8, 2·0, 1·4 grm. Mean of first five measurements = 1·48 grm.; mean of second five measurements = 1·44 grm.; mean of all 1·46 grm.

B. *Brass.* 10 measurements: Pressure = 1·6, 2·0, 2·2, 2·2, 2·0, 2·2, 2·2, 2·2, 1·6, 1·7 grm. Mean of first five measurements = 2·00 grm.; mean of second five measurements = 1·98 grm.; mean of all 1·99 grm.

C. *Iron* (rolled). 10 measurements: Pressure = 2·2, 1·8, 2·0, 1·6, 2·2, 2·0, 2·2, 1·8, 2·0, 1·8 grm. Mean of first five measurements = 1·96 grm.; mean of second five measurements = 1·96 grm.; mean of all 1·96 grm.

D. *Glass* (object glass for microscope). 10 measurements: Pressure = 3·8, 4·0, 4·2, 4·0, 4·0, 3·8, 4·2, 4·2, 4·2, 4·4 grm.

Mean of first five measurements = 4·0 grm.; mean of second five measurements = 4·16 grm.; mean of all 4·08 grm.

Measurements with steel point (sewing needle, number 5 sharp):

E. *Copper.* 10 measurements: Pressure = 5·0, 4·8, 4·0, 4·8, 4·0, 4·2, 3·8, 4·2, 4·2, 4·0 grm. Mean of first five measurements = 4·52 grm.; mean of second five measurements = 4·08 grm.; mean of all 4·3 grm.

F. *Brass.* 10 measurements: Pressure = 16·4, 12·0, 10·4, 10·4, 9·8, 14·0, 13·0, 10·8, 10·8, 10·4 grm. Mean of first five measurements = 11·8 grm.; mean of second five measurements = 11·8 grm.; mean of all 11·8 grm.

The ten measurements were made each time on the same piece of copper, brass, etc. with the same inclination of the surface and the same direction for the scratch. After each scratch the plate was moved a little to one side by means of the screw (1) so that the ten scratches were parallel and near each other.

The beginning of the scratch with the diamond point was always sharp and easily seen and is a very distinct point. With the steel needle, however, the beginning of the scratch on steel was somewhat uncertain. The scratch did not have a sharp beginning but was microscopic and gradually increased in depth with the increase of pressure.

In general a diamond point will probably give the best results for all substances except possibly for those which are extremely soft. Special study is being made to determine this point.

The nearly equal results obtained by scratching iron and brass with diamond were surprising and the two were tested against each other. The iron made a scratch on the brass very easily and the brass made a scratch on the iron but apparently with greater difficulty, but the point on the iron was, however, sharper than the point on the brass. It would appear that in the determination of hardness other properties such as tenacity, elasticity, flexibility, etc. must be taken into consideration, and it is hoped that this instrument may be of assistance in the study of the relations between these properties.

The results show a good determination when the mean of five measurements is taken.

The measurement is rapid and requires less than three minutes for a measurement when the test object is in position or for ten consecutive measurements less than a half hour.

The advantages of the instrument above mentioned are rapidity of observations, compactness, and cheapness. So far as observations have been made up to the present time, the instrument gives good results for polished faces of glass and metal, but further study is necessary to show its availability for minerals.

Heidelberg, Aug. 14, 1909.

ART. X.—*Dodecahedral Jointing due to Strain of Cooling;* by FRED. H. LAHEE.

IN the woods just south of Beacon St., and about a quarter of a mile west of Hammond St., Chestnut Hill, Mass., the Roxbury conglomerate is cut by a fine-grained, basaltic dike* which, in some parts, disintegrates into small (average diameter, ¼ in.), polyhedral, often roughly dodecahedral, fragments. The dike has approximately plane-parallel sides, is four feet thick, strikes N. 20° E., and dips 78° E., its attitude being parallel to a prominent joint set of the country rock. That it entered a relatively cool rock is indicated by the fact that its texture, moderately fine in the middle, becomes very fine at the contact. It contains occasional large phenocrysts (xenocrysts) of apatite and biotite, both of which are well shaped, and of pink acid feldspar, which has outlines made irregular by the invasion of short tongues of the groundmass.

Near the country rock, on each side, in a zone from four to ten inches wide, hexagonal columnar jointing is poorly developed perpendicular to the contact surface. Inwards, the columns give place to the polyhedral blocks already mentioned as conspicuous in the disintegration of the rock.

Obviously the joints† which give rise to such many-sided fragments are of small extent. Furthermore, they (the joints) often vary in direction, or may die out entirely; but in spite of this irregularity, it is not difficult to find blocks bounded by twelve rhombohedral faces that intersect one another at angles nearly equal to the similar angles of a perfect dodecahedron. The surfaces of the blocks are relatively coarsely granular, without a well-developed feather fracture, a feature not uncommon on the more finely textured hexagonal columns. Where the phenocrysts are in the path of fracture, the break either passes round the obstacle, or takes advantage of the mineral cleavage. These statements clearly point to the inference that the dodecahedral jointing, like the hexagonal, is an effect of tension due to cooling.

Hexagonal columnar jointing has long been so interpreted. In the ideal case, according to the principles of least action, the columns begin their development as a series of three-way fractures (each fissure at an angle of 120° to the other two) radiating from equally spaced points in a surface which is perpendicular to their (the columns') direction of growth. This type of fracture is therefore a two-dimensional, or surface, phenomenon, and the extension of the columns may be regarded as the result of the regular inward advance of successively cooler planes, for each of which the temperature is uniform throughout.

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* The writer wishes to thank Mr. R. W. Sayles for bringing this dike to his notice, and Professor Chas. Palache and Professor J. B. Woodworth, who discovered the dodecahedral jointing, for valuable suggestions.

† Similar jointing has recently been seen by the writer in trap dikes on Ragged Island, Casco Bay, Maine.

If, on the other hand, we conceive of a *solid* which is losing heat equally in all directions and in such a way as to be subjected to a homogeneous strain, *six-way* fracture will develop instead of the *three-way* fracture of the cooling *surface*, and the resulting geometrical form will be a *dodecahedron* instead of a *hexagon*.

As hexagonal fracture may be illustrated by considering a series of equal tangent circles compressed uniformly from all directions in the same plane, so dodecahedral jointing may be experimentally demonstrated by subjecting a group of equal tangent balls, arranged in superposed horizontal layers, to equal pressure from every direction. Those spheres which were originally in contact with twelve others will, it is true, be dodecahedral; but whether they become regular rhombic dodecahedra or forms which, to borrow from crystallography, resemble a regular rhombic dodecahedron twinned parallel to an octahedral face, will depend on whether the centers of the balls of a given horizontal layer were above the centers of the spaces, or of the spheres, of the second layer below. In either case, prior to the compression, the conditions of unoccupied space and of equal distance between the centers of spheres will be fulfilled.

The literature appears to be lacking in references to the particular kind of jointing described. Much of the work on this subject was done several decades ago. At that time hexagonal jointing received considerable attention and was correctly explained as the result of uniform strain in a surface. Spheroidal structure, which was shown by Bonney to be often unrelatedto fracture systems, was, however, held to be the analogous phenomenon in a solid, and perlitic structure was consigned to the same catagory. Bonney thus states his views:* "A hexagon is the figure which will result from uniform contraction in two dimensions, a sphere from contraction in three dimensions." The case in point, however, leads to the conclusions: (1) that hexagonal columnar jointing is caused by equal tension in all directions in a surface at right angles to which the strain is differential; and (2) that uniform contraction in a solid must, under corresponding conditions of homogeneity, give rise to dodecahedral jointing. The sphere cannot be the exact analogue of the hexagon.

Cambridge, Mass.

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* Bonney, T. G., On Columnar, Fissile, and Spheroidal Structure. Quart. Jour. Geol. Soc., Lond., xxxii, p. 152, 1876. On this subject see also Jukes, J. B., and Geikie, A., Student's Manual of Geology, 3d ed., 1872, pp. 182, 183, 311; Mallet, R., Phil. Mag., Ser. 4, vol. i, pp. 122, 201; Scrope's Volcanoes of Central France, p. 92; Iddings, J. P., The Columnar Structure in the Igneous Rock on Orange Mountain, New Jersey, this Journal, (3), xxxi, p. 321, 1886, and Iddings, J. P., Igneous Rocks, N. Y., 320, 1909.

ART. XI.—*Restoration of Paleolithic Man;* by RICHARD SWANN LULL. (With Plate I.)

[Contribution from the Paleontological Laboratory, Peabody Museum, Yale University.]

AN attempt has recently been made by the writer to restore in plastic form the type of mankind dwelling in Europe during a portion of the Paleolithic period and variously known to science under the names of *Homo primigenius*, *neanderthalensis* or *mousteriensis*. The restoration, which is life size, is a tentative one and will be kept in the clay for a time in order that authoritative criticism may be met before it is cast in plaster (cf. Plate I).

The model is based mainly upon what is known as the "Man of Spy No. 1"; one of the two specimens found at Spy in Belgium, of which the museum contains excellent plaster casts. The illustrations of the remains of man found at Krapina in Croatia and described by Professor Gorjanovic-Kramberger in his "Der Diluviale Mensch von Krapina in Kroatien" 1906, were largely used, together with certain other measurements, such as the estimate for total height, etc. For the use of the casts and the assembling of data, together with kindly criticism, I am indebted to Dr. George Grant MacCurdy, Curator of Anthropology in this museum, while to Professor Joseph Barrell, who has taken a very lively interest in the work, I wish also to acknowledge my gratitude.

My conception of *Homo primigenius* is that of a man of low stature, standing only five feet three inches in height, but of great physical prowess as indicated by the robustness of the limb-bones and especially of their articular ends. The great paunch of the higher anthropoid apes, which are almost exclusively vegetarians, is lacking and in its place is shown the clean-cut, athletic form of torso such as one sees in the typical North American Indians, for I imagine food conditions were much the same. We have abundant evidence that Paleolithic man was a crafty hunter, for the remains of various animals which he slew for food are found in the bone breccias of the caverns wherein his own relics are entombed. Great power is indicated, however, in the upper portion of the trunk and in the arms, compensating this ancient type for his lack of adequate tools and weapons.

The knees are somewhat flexed as the curved thigh bone would indicate, and probably should be more so, and the trunk is only partially erect, for the inward curves of the back bone, so characteristic of modern man, are but feebly developed, as in the case of babes of the present day or in individuals bowed down by the weight of years. The shin is relatively short, as with certain present-day races, and the great toe somewhat offset though having long since lost its ape-like opposability.

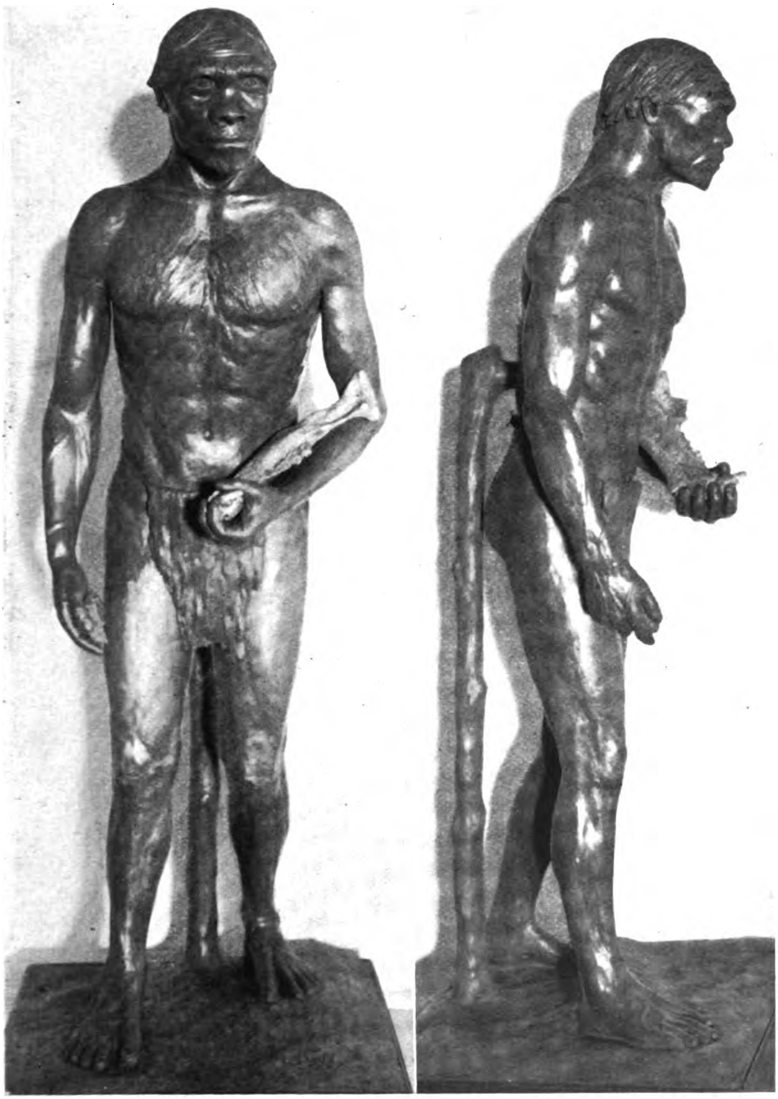
The head shows the prominent supra-orbital ridges above the deep-set eyes; the low, flat forehead; the broad, concave, nasal bridge and the somewhat prognathous jaws. The lower jaw is deep and powerful, and lacks the characteristic chin prominence of modern man. Other restorations give a greater prognathism than mine, and it may be that here I am in error in showing too great a refinement of countenance as compared with the low type of calvarium. The contour of the jaw is based upon actual measurement of one of the Krapina specimens and one should bear in mind that the far older jaw recently brought to light at Heidelberg, though of a more brutal type than any yet known, shows less dental prognathism than do the modern negroes, indicating a very great antiquity for the radiative evolution of the several human stocks.

In all probability the men of that day were much more hairy than the model would indicate, as they had little or no clothing and the climate, during part of their racial career at least, was severe. They were, however, cave dwellers and knew the use of fire. I have purposely refrained from indicating this conjectural character, as it would, to a certain extent, conceal the conformation of the underlying parts.

A jaw of the cave bear, *Ursus spelæus*, a contemporary animal, though now long since extinct, is borne in the left hand, while the right contains a chipped stone implement from one of the typical stations, thus indicating the cultural plane of the race.

This type dwelt in Europe before the last glacial period, estimated at from 100,000 to 200,000 years ago, and continued for a long period of time, for his remains are found entombed successively with both cold and warm climate animals. The relics are found within or near rock shelters and caves, the best known of which are those of Neanderthal, Germany; Spy, Belgium; Krapina, Croatia; Le Moustier and La Chapelle-aux-Saints in France. As a race *Homo primigenius* is to-day entirely extinct, though whether he was blotted out or absorbed by the invading horde of the superior *Homo sapiens* we have no certain knowledge. Occasionally, however, something of his type appears in modern man, notably in St. Mausberg, a medieval Bishop of Toul, and in Lykke, a scientific Dane of the eighteenth century, as well as among Australians and Melanesians, the lowest living races of mankind. These may be looked upon as instances of atavistic reversion.

The "Man of Spy," while showing more pithecoid characters than his successor, was nevertheless eminently human, representing as he does the type just preceding modern man, and one far removed from a true ape-like ancestry. In the popular conception "Prehistoric man" should be gorilloid, or at any rate distinctly simian; against this misconception the model stands as a silent protest.



RESTORATION OF PALEOLITHIC MAN.

ART. XII.—*Bismite;* by W. T. SCHALLER and F. L. RANSOME.

IN the Goldfield district in Nevada, bismite occurs in the January, Combination, Sandstorm, and probably also in other mines, as minute, pearly scales with brilliant luster and of silvery whiteness. The luster of the scales is almost metallic and suggests at first glance delicate and untarnished crystals of native silver. The mineral is limited to the oxidized zone, is usually accompanied by limonite and is frequently associated with rich ore. It occurs as single glittering scales or specks on the walls of cavities in spongy limonite or rusty ledge-matter, as delicate frost-like films on the same materials and as spongy aggregates with quartz. In the last-named form it is clearly pseudomorphous after bismuthinite, the material having consisted originally of a mass of bismuthinite prisms held together by a siliceous gangue. The prismatic structure of the bismuthinite is retained as hollow casts in the quartz, lined or partly filled with scales of bismite.

As natural crystals of bismite do not appear to have been found hitherto and as the mineral has been assigned to the orthorhombic system in Dana's and Hintze's mineralogies on the basis of Nordenskiöld's work on artificial crystals in 1860 and 1861, considerable interest attaches to the Goldfield occurrences on account of the crystallinity of the material.

When examined under the microscope in gently powdered material the crystals appear as thin colorless scales, with occasionally a suggestion of hexagonal outline. On account of their tenuity, it is rare that an edge view of a scale is obtainable. The larger flat-flying scales are dark in all positions between crossed nicols and give a negative uniaxial figure with convergent light. There are no colored rings and the double refraction is apparently not great. The refractive index, on the other hand, is rather high, being greater than that of anorthite. The mineral has a perfect basal cleavage and the scales, viewed without the analyzing nicol, commonly show delicate interference colors due to the refraction and reflection at the surfaces of the exceedingly thin cleavage sheets.

Some of the best material obtainable was analyzed with results as follows:

	1	2	3	Average
Insol. in HCl, mostly quartz gangue	78·95	78·87	79·01	78·94
Bi_2O_3	17·29	17·00	16·84	17·04
H_2O (loss on ign.)	3·96	....	....	3·96
Fe_2O_3	0·36	0·50	0·21	0·36
				100·30

The results show that the mineral is either bismite or else a hydrous oxide of bismuth. If the latter be the case, the mineral is a new species (providing, of course, that Bi_2O_3 is the correct formula for the bismuth ocher found in nature and called bismite). Attempts to isolate a sufficient quantity of the pearly scales from the gangue for separate analysis were not successful.

The minute, tabular crystals are too incomplete to allow of a determination of their geometrical form by crystallographic measurements alone. From the uniaxiality of the crystals, their hexagonal outline, triangular markings on the base and distribution of the faces as far as seen, reference of them to the rhombohedral division of the hexagonal system appears to be justifiable.

The value of the *c* axis, derived in a manner presently to be described, is 0·5775. Seven faces are determined as present; the base, five positive and one negative rhombohedra. Besides these, there are indications of two more positive rhombohedra. A brief description of these forms follows.

c $\{0001\}$. Always very large, even, and highly polished. Sometimes shows triangular markings or striæ, the faces parallel to these markings being taken as positive.

o $\{10\bar{1}6\}$. Occurs on two crystals, as broad faces giving, however, poor reflections. One face was considerably striated, giving two signals a degree apart.

q $\{10\bar{1}5\}$. Broad faces giving fairly good reflections.

u $\{10\bar{1}4\}$. Narrow faces, one striated wlth a fair reflection, and one as a line face giving a very poor reflection.

k $\{10\bar{1}3\}$ Usually as a line face, striated and giving a very poor reflection.

? $\{20\bar{2}5\}$. A doubtful face, narrow, giving no distinct signal.

? *d* $\{10\bar{1}2\}$. Another doubtful face, broad, giving no distinct reflection.

y $\{20\bar{2}1\}$. Line faces, giving exceedingly faint reflections.

z $\{01\bar{1}1\}$. The only negative rhombohedron observed. Very faint line faces, giving no reflection. Its negative position could be determined only on crystal No. 6.

The measurement of the forms are shown below.

			Meas.		Calc.
(0001)	:	$(10\bar{1}6)$	6° 37′	6° 41′	6° 21′
"	:	$(10\bar{1}5)$	7 33	7 36	7 36
"	:	$(10\bar{1}4)$	9 31	9 31	9 28
"	:	$(10\bar{1}3)$	12 11	12 26	12 32
			13 18	12°–14°	
"	:	$(20\bar{2}1)$	54°	54°	53 08
"	:	$(01\bar{1}1)$	35°	32½°	33 42

Doubtful forms:	Meas.	Calc.
(0001) : $(20\bar{2}5)$,	15°	14° 56′
" : $(10\bar{1}2)$,	16°–20°	18 26

The value for the c axis was obtained from three measurements that were considered as the most accurate. The others gave values agreeing fairly well with the one adopted, as is shown below. The crystals were measured on the two-circle goniometer and the ρ angle for these forms is the angle between that form and the base.

The three best measurements are:

$\rho\ \{10\bar{1}5\}$	= 7° 33′	p_0 = ·6627	cryst. No. 1
$\rho\ \{10\bar{1}5\}$	= 7 36	" = ·6672	" " 4
$\rho\ \{10\bar{1}4\}$	= 9 31	" = ·6706	" " 2

Av. p_0 = ·6668 ; c = 0·5775.

An average of the other measurements gave values closely agreeing. Thus:

$\rho\ \{10\bar{1}6\}$	= 6° 37′	p_0 = ·6960	cryst. No. 3
"	= 6 41	" = ·7031	" " 6
$\rho\ \{10\bar{1}4\}$	= 9 31	" = ·6706	" " 6
$\rho\ \{10\bar{1}3\}$	= 12 11	" = ·6477	" " 6
"	= 12 26	" = ·6614	" " 4
"	= 13 18	" = ·7102	" " 1

Av. = ·6815

The following measurements of faces giving no distinct reflections also showed close agreement:

$\rho\ \{10\bar{1}3\}$	= 12°–14° (av. 13°)	p_0 = ·69	cryst. No. 1
$\rho\ \{20\bar{2}5\}$	= 15°	" = ·67	" " 2
$\rho\ \{10\bar{1}2\}$	= 16°–20° (av. 18°)	" = ·65	" " 1
$\rho\ \{01\bar{1}1\}$	= 35°	" = ·70	" " 5
"	= 32½°	" = ·64	" " 6
$\rho\ \{20\bar{2}1\}$	= 54°	" = ·69	" " 1
"	= 54°	" = ·69	" " 6

The values for p_0 just given show that the interpretation of the forms is the correct one.

Of the six crystals (all incomplete) that were measured, only two need to be briefly described.

Fig. 1*a* is an orthographic projection of a crystal (No. 1), showing the trigonal distribution of the rhombohedra, and the triangular markings on the base.

Fig. 1*b* shows a similar projection of cryst. No. 6, with a negative rhombohedron.

An odd feature of these crystals is that the development of the faces is so uneven, that no two faces of the same form are present on the upper half of a crystal, though this is in part due to the incompleteness of each crystal.

From the foregoing observations it appears that the natural bismite is not orthorhombic but belongs to one of the uniaxial systems, probably the hexagonal. Its presence in oxidized ore appears to be uniformly indicative of bismuthinite in the original sulphide ore. Some migration, however, has taken place during oxidation and the scales of bismite do not always occupy the exact positions of the parent needles of bismuthinite.

Fig. 1*a*.

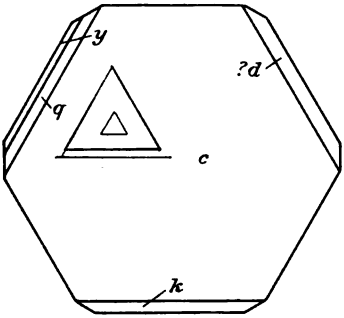
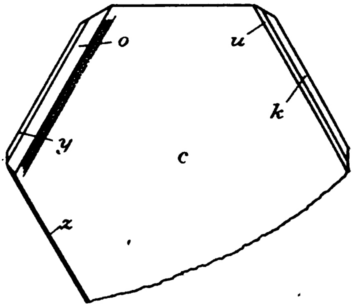


Fig. 1*b*.



U. S. Geological Survey,
Washington, D. C.

ART. XIII.—*Contributions to the Mineralogy[*] of Franklin Furnace, N. J.;* by CHARLES PALACHE.

THE purpose of this paper is to present in brief form some of the more interesting results obtained in the study, continued through several years, of the minerals of Franklin Furnace, New Jersey. The complete results of the study will, it is hoped, appear soon in monograph form, but it seems desirable to place on record without further delay the chemical analyses made for the most part in the laboratory of the Geological Survey. These analyses are either of minerals not before recorded from this locality or of species concerning which our information is incomplete. With these are also included crystallographic notes on a number of species and a list of additional minerals whose presence at Franklin Furnace has not hitherto been recorded.

Arsenopyrite: Crystal Form, Composition.

Brilliant crystals of arsenopyrite up to an inch in length were found in several of the limestone quarries at Franklin Furnace in 1905. They are associated with pyrite, pyrrhotite, spinel, humite, tourmaline and phlogopite. The crystals are completely developed, showing besides known forms the new pyramids (532), (112), (143), and (132), the first present on all crystals and characteristic for the locality.

The following analysis by E. C. Sullivan, U. S. G. S., was made of selected crystal fragments:

		Ratio	
Fe	32·48	·581	1
Co	1·16	·02	
As	48·72	·650	1·08
S	18·80	·587	·98

The ratio shows a normal composition. The presence of cobalt is interesting; it has been shown by Kraus & Scott[†] to be present in about the same proportion in pyrite crystals in the same limestone. Tests for cobalt made on the associated pyrrhotite showed no trace of this element and hardly more than a trace of nickel.

Fluorite: Composition.

The following analysis of fluorite by G. Steiger, U. S. G. S., was made in the belief that it was a manganiferous variety.

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[*] Published by permission of the Director of the U. S. Geological Survey.

[†] Zeitschr. für Kryst., xliv, 144, 1907.

The material was pale red and granular, the matrix of franklinite grains.

Ca	51·21	Al	0·18
Mg	0·24	F	45·85
Fe	0·27	Cl,Co_2	none
Mn	0·09		
			97·84

Mr. Steiger remarks that the deficiency in the analysis is doubtless due to fluorine.

The manganese content is insignificant. If the total deficiency, 2·16 per cent, is calculated as fluorine, there is still slightly less than is required to form RF_2 with all bases, but almost exactly enough to satisfy the calcium. This suggests, but of course does not prove, that the bases other than calcium are present as impurities in the form of unknown compounds.

Manganosite: Occurrence, Composition.

This rare substance, known hitherto only from two Swedish localities, was found in a single specimen in the Harvard Mineralogical Museum. The specimen consists of a granular aggregate of franklinite, zincite and manganosite. The latter is in irregular grains showing cubic cleavage, dark green in the mass, emerald-green in thin fragments. The material analyzed contained traces of zincite and minute black films of manganese oxide. The specific gravity was 5·364.

1. Manganosite: analysis by George Steiger, U. S. G. S.
2. Same corrected for ZnO and MnO_2 known to be present.

	1	2
MnO	94·59	99·61
MnO_2	1·30	----
ZnO	3·41	----
FeO Fe_2O_3	0·26	0·27
MgO	0·11	0·12
H_2O-	0·38	----
H_2O+	0·40	----
	100·45	100·00

The material is thus shown to be very nearly of the theoretical composition of manganosite, MnO.

Zincite: Crystal Form.

Measurements of natural crystals of zincite are very few and poor and the generally accepted axial ratio for the species is based on artificial crystals. The writer obtained measurements on one crystal of zincite from Franklin Furnace, however, which were very satisfactory; he has therefore calculated an axial ratio based on them and in the following table gives all the measurements made on natural crystals and the corresponding angles calculated from (1) the new ratio, (2) Dana's ratio, (3) Traube's ratio based on artificial crystals. The author's measurements were on four faces of the pyramid $(40\bar{4}5)$, the angle to the base (average) being 55° 42′ with deviation of but 4′. A single reading (0001) to $(10\bar{1}1)$ was also obtained, in close agreement.

Angle	Calculated			Measured				
	Dana $a:c=$ 1:1·6219	Traube $a:c=$ 1:1·6077	Palache $a:c=$ 1:1·5870	Dana '86	Grosser '92	Moses '95	Palache	
							Contact	Reflexion
$0001 \wedge 10\bar{1}1$	61°54′	61°41′	61°23′	....	....	....	62°00′	$61°2\bar{2}'$
$10\bar{1}1 \wedge 01\bar{1}1$	52 21	52 14	52 04	....	....	....	52 00	* ....
$0001 \wedge 40\bar{4}5$	56 17	56 03	55 42	....	55°38′	55°40′	....	55°42′
$40\bar{4}5 \wedge 04\bar{4}5$	49 09	49 00	48 48	....	48 50	....	....	....
$0001 \wedge 50\bar{5}4$	66 52	66 41	66 25	65°20′	....	....	....	....
$50\bar{5}4 \wedge 05\bar{5}4$	54 46	54 40	54 33	53 53	....	54°42′	....	....

Gahnite, variety Dysluite: Composition.

Following is an analysis of a gahnite crystal supplied by Mr. Canfield from the locality at Sterling Hill which yielded the enormous crystals in the Canfield Collection. This is the type of the variety dysluite but has not been before analyzed. Specific gravity 4·56.

1. Analysis of dysluite, W. T. Schaller, U. S. G. S., 1906.
2. Same omitting SiO_2, CO_2 and equivalent of CaO, and H_2O. State of oxidation of iron and manganese not known.

	1	2	Mol. Ratio	
Al_2O_3	47·27	48·81	·478	·542=1
Fe_2O_3	9·90	10·22	·064	
ZnO	37·10	38·31	·472	·523=1·04
MnO	0·93	0·97	·013	
MgO	1·09	1·12	·028	
CaO	1·01	0·57	·01	
CO_2	0·38	....		
SiO_2	1·47	....		
H_2O	1·21	....		
	100·36	100·00		

The composition of dysluite is very like that of the gahnite from Franklin Furnace analyzed by Brush, both being very high in zinc.

Franklinite: Form, Composition.

Small implanted crystals of franklinite of quite abnormal appearance were seen in two specimens believed to have come from the Hamburgh mine, Franklin Furnace. The crystals are of adamantine luster and on edges or where splintered show a deep red color. The prevailing habit is cubo-octahedral with occasional planes of the forms (101), (311), (211) and (310). The unique color and habit of these crystals suggested a new type of the spinel group, but the analysis below by W. T. Shaller, U. S. G. S., shows them to be of ordinary franklinite composition. Specific gravity 5·09.

*Fe_2O_3	66·58	CaO	0·43
*MnO	9·96	MgO	0·34
ZnO	20·77	H_2O	0·71
			99·51

Hetærolite: Form, Composition.

Reëxamination of this mineral, which has been a doubtful species because of Moore's incomplete description, establishes the correctness of his characterization as a zinc hausmannite.

Tetragonal, shown by optical behavior of the fibers under the microscope. Indistinct prismatic cleavage, specific gravity 4·85.

Composition $ZnO.Mn_2O_3$, as shown by the following analysis of material furnished by E. P. Hancock:

1. Hetærolite, analysis by W. T. Schaller, U. S. G. S., 1906.
2. Same corrected for the small amount of SiO_2 and for water probably contained in a slight admixture of chalcophanite.

	1	2	Ratio.	
Mn_2O_3	60·44	63·85	·405	1
Fe_2O_3	·77	0·83	·005	
ZnO	33·43	35·32	·435	1·06
SiO_2	1·71			
H_2O-	2·47			
H_2O+	1·42			
	100·24	100·00		

Hausmannite, $MnO.Mn_2O_3$
Hetærolite, $ZnO.Mn_2O_3$

Pyroxenes: Composition.

Manganese- and zinc-bearing varieties of pyroxene are characteristic both of the granite and of the intruded rocks near the contacts at Franklin Furnace and Stirling Hill. The dis tinctions between these pyroxenes are not sharply defined. Jeffersonite, the most abundant of them, contains manganese zinc and iron in addition to lime and very little magnesium. Zinc schefferite differs in the practical absence of iron and in the increase of calcium and magnesium at expense of manganese and zinc. Schefferite, close to the last named, contains no zinc, little iron and a larger proportion of magnesium. Schefferite was found only in well-defined crystals in limestone from Stirling Hill. The analyses here given are of a very fresh jeffersonite from Parker shaft, Franklin Furnace, and of schefferite which has not been before described from this region.

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* State of oxidation of iron and manganese not known.

1. Analysis of jeffersonite, Steiger, U. S. G. S., 1906.
2. Analysis of schefferite, Schaller, U. S. G. S., 1907.

	SiO_2	CaO	MgO	MnO	ZnO	FeO	Al_2O_3	Fe_2O_3	H_2O-	H_2O+	Na_2O	CO_2
1	49·03	19·88	5·81	7·91	7·14	3·95	0·86	4·22	0·60	0·70	....	....
											[100·14	
2	49·80	21·07	12·35	9·69	tr.	1·61	0·26	1·46	1·55	1·31	0·9	0·43
								[F = 0·31 = 99·93 less ·13 = +				

Nasonite: Crystal Form.

The crystal form of nasonite could not be determined by Penfield in the absence of crystals, but he concluded that it was tetragonal because of chemical analogy with ganomalite—a tetragonal mineral.

Crystals of nasonite were intrusted to the writer by Mr. Canfield, who had recognized their hexagonal character. One of them proved measurable and showed the forms a $(11\bar{2}0)$, m $(10\bar{1}0)$, p $(10\bar{1}1)$ and x $(90\bar{9}2)$, the hexagonal symmetry being well defined. The axial ratio, based on two measurements of angle $c \wedge p = 56° 40'$, is $a:c = 1: 1·3167$.

Angle $c \wedge x$, calculated 81° 41′, measured 81° 36′.

The faces of m are cavernous except at the prism edges, where they are well defined and generally truncated by a. The prism rounds over into the pyramid p on most of the small crystals seen, the form x representing a plane face t in this surface on one crystal. The faces of p were dull on all except the measured crystal. This was afterwards tested qualitatively and gave the reactions of nasonite.

Glaucochroite: Crystal Form.

Terminated crystals were not present in the original specimens of glaucochroite described by Penfield, but he obtained an approximate axial ratio by measurement of the inclination of individuals in twin position.

Two terminated crystals were secured from a specimen loaned by the Foote Mineral Co. which yielded fair measurements, determining the following axial ratio and forms.

$$a : b : c = \cdot 4409 : 1 : \cdot 5808$$
$$= \cdot 440 : 1 : \cdot 566 \text{ (Penfield).}$$

Forms: *a* (100), *b* (010), *m* (110,) *s* (120), *x* (103), *h* (021) *e* (111), *f* (121).

Combinations: 1. *b. m. s. x.*
2. *a. b. m. s. k. e. f.*

Angles:	Calculated		Measured		
	ϕ	ρ	ϕ	ρ	
111	66°12′	55 13	66 13	55 15	2 faces good
121	48 36	60 12	49 22	60 29	1 face poor
110	69 12	90 00	66 09	90 00	4 faces good
120	48 36	90 00	49 14	90 00	poor

Bementite: Composition, System.

The description of bementite by Koenig was incomplete and its relations were not clear. Study of a later find of better material from the Parker shaft, Franklin Furnace, establishes its close relationship to tephroite in system and composition.

System orthorhombic, shown by three pinacoidal cleavages at right angles but unequally perfect; and by a symmetrical biaxial interference figure with small axial angle seen on plates parallel to the best cleavage.

The analysis given below agrees closely with that of Koenig, but the water is shown to be constitutional, coming off for the most part at a red heat. It leads to the formula $H_6Mn_5(SiO_4)_4$ with more or less replacement of manganese by iron, zinc and magnesium. This is analogous to the formula of tephroite, which may be written $Mn_8Si_4O_{16}$; in bementite three molecules of manganese are replaced by constitutional water. That it is not a simple case of partial hydration is shown by the optical homogeneity of the bementite crystals.

1. Analysis of bementite, Geo. Steiger, U. S. G. S., 1906.

2. Same recalculated to 100 per cent after omitting Al_2O_3, Fe_2O_3 and H_2O— and substituting for FeO, MgO, CaO, and ZnO, equivalent amounts of MnO.

3. Theory for $H_6Mn_5(SiO_4)_4$.

	SiO_2	MnO	FeO	ZnO	MgO	CaO	H_2O+	H_2O-	Al_2O_3	Fe_2O_3	
1	38·36	39·22	4·94	2·93	3·35	0·62	8·01	0·60	0·96	0·71	99.70
2	37·93	53·56					8·51				100·00
3	37·18	54·53					8·29				100·00

Willemite: Axial Ratio, Refractive Indices.

No accurate measurements of willemite crystals from New Jersey have been hitherto recorded. The fundamental angle employed by Dana was based on contact measurements of troostite. Other authors use the element determined by Lévy on crystals from Moresnet, on which the sole form is a rhombohedron not found on Franklin crystals. A number of measurable crystals, all from the Parker shaft, Franklin Furnace, passed through the writer's hands and the data secured from them permit the establishment of a satisfactory axial ratio. The five measured crystals were colorless or pale green prisms terminated by the base and one or both of the rhombohedrons *e* (01$\bar{1}$2) and *r* (10$\bar{1}$1).

Angle $c \wedge e$, 19 readings average 20° 47′, limits 20° 35′—21° 04
" $c \wedge r$, 14 " " 37° 35′, " 37° 20′—37° 40′

Whence $a : c = 1 : 0·6612$
Lévy " $= 1 : 0·6696$
Dana " $= 1 : 0·6775$

Calculated angle, $c \wedge e = 20° 53′$
" " $c \wedge r = 37° 22$

Refractive indices, measured on a prism || *c*.
Sodium light, $\omega = 1·69390$ $\epsilon = 1·72304$
Lithuim " $\omega = 1·68897$ $\epsilon = 1·71812$

Friedelite: Occurrence; Composition.

Friedelite has not been before described from America. It was identified by the writer on a single specimen from Buckwheat mine, Franklin Furnace, in the Kemble Collection, and in minute amount on specimens from the Parker shaft. The mineral occurs in scales or tabular crystals with the unit rhombohedron and base, not measurable.

The analysis, with others for comparison, follows:

1. Friedelite, Franklin Furnace, Schaller, U. S. G. S., 1906.
2. Same recalculated to 100 per cent after removing H_2O— and substituting equivalents of MnO for FeO, MgO, ZnO and CaO.
3. Average of four analyses of friedelite (Dana, System and 1st Appen.) recalculated as in number 2 above.
4. Theory for $H_9\,(MnCl)\,Mn_7\,(SiO_4)_6$
5. Theory for $H_{20}\,(MnCl)_2\,Mn_{14}\,Si_{12}O_{49}$
6. Theory for $H_{16}\,(MnCl)_2\,R_{11}\,Si_{10}\,O_{40}$ (Zambonini).

	1	2	3	4	5	6
SiO_2	34·69	34·95	34·14	34·73	34·43	34·84
MnO	48·00	53·22	54·35	54·80	54·33	53·60
Cl	3·43	3·45	3·42	3·42	3·39	4·12
H_2O+	9·08	9·15	8·84	7·82	8·60	8·36
H_2O-	1·94					
FeO	1·45					
MgO	·98					
ZnO	1·05					
CaO	·63					
	101·25	100·77	100·75	100·77	100·75	100·92
Less O = Cl	·77	·77	·75	·77	0·75	·92
	100·48	100·00	100·00	100·00	100·00	100·00

The Franklin friedelite agrees closely in composition with that of other localities, as shown by comparison of columns 2 and 3. Groth's formula for the mineral, used by Dana, does not well express the results of these analyses, which uniformly give a higher content of manganese or its equivalents and a lower content of chlorine than demanded by it. The formula adopted here, $H_9(MnCl)Mn_7(SiO_4)_6$, is satisfactory as to all constituents save water, for which it is too low. The formula $H_{20}(MnCl)_2Mn_{14}Si_{12}O_{49}$, obtained by adding one-half molecule of water to the latter, comes nearest to the exact equivalent of the analytical data but was rejected as not being reducible to the orthosilicate form. Zambonini* has derived for pyrosmalite and friedelite the formula

$$RCl_2.12RO.10SiO_2+8H_2O$$

an expression which takes no cognizance of the fact that the water in these minerals is combined. The above formulas, reduced to this form of expression, are:

$$(1)\ RCl_2.15R_2O.12SiO_2+9H_2O$$
$$(2)\ RCl_2.15RO.12SiO_2+10H_2O$$

This formula of Zambonini gives a composition very similar to (2) and quite as close to the analytical results except for chlorine, which is too high. It is better than (1) as to water but is no closer in regard to other constituents.

Vesuvianite, variety Cyprine: Analysis.

Bluish green fibrous vesuvianite corresponding in character with the Norwegian cyprine was found in 1905 in granite from the Parker shaft. The material was carefully freed from minute specks of metallic copper and had a specific gravity of 3·451. The analysis by Steiger, U. S. G. S., 1907, follows:

SiO_2	36·41	PbO	trace
Al_2O_3	17·35	Na_2O	0·44
Fe_2O_3 FeO	1·86	K_2O	0·50
		H_2O-	0·24
MgO	1·38	H_2O+	3·51
MnO	1·75	F	0·36
ZnO	1·74		
CuO	1·85		100·23
CaO	33·21	less O = F	0·17
		Sum	100·06

This analysis agrees closely with that of the cyprine from Tellemarken save in the greater amount of water and less fluorine. It corresponds to the formula:

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* Zeitschr. Kryst., xxxiv, 554.

$$H_8(Al,Fe)_6Ca_{12}Si_{10}O_{45}$$

with part of the lime replaced by a number of oxides.

Datolite: Crystal Form.

Datolite has been known for some time from the Parker shaft, Franklin Furnace, but crystals have not hitherto been described from there. Complex crystals were found in a specimen in the Harvard Collection on which were observed a number of forms including several new to the species. In the following list new forms are marked with an asterisk:

a (001)	*e* (023)	*x* (101)	*γ*· (221)	*ε*· $(\bar{1}11)$	*f*: (241)	*k* : $(\bar{2}45)$
c (100)	M (011)	*I (304)	Λ· (111)	*a*· $(\bar{2}21)$	*j* : (243)	
g (110)	*o* (021)	*φ* (102)	*θ*· (112)	*Q*· (121)	**d* (263)	
m (120)	**q*: (701)	*ζ* $(\bar{1}01)$	Y· $(\bar{2}23)$	*μ*· $(\bar{2}11)$	**k*· (475)	

Symbols and letters after Goldschmidt, Winkeltabellen.

The pyramid *d* (263), new to datolite, is present on all the crystals with characteristic form.

Cuspidine: Occurrence; Composition.

The occurrence of this mineral, known hitherto solely from Vesuvius, at Franklin Furnace is established by the following analysis, for which the writer is indebted to Dr. C. H. Warren.

The material, which occurred with nasonite, was isolated by hand-picking and heavy solution and analyzed by him at the time (1899) Penfield and Warren were working on nasonite and other peculiar silicates from the Parker shaft. At the time no satisfactory interpretation of the analysis was hit upon, the identity of the mineral remained hidden, and, all the material having been used in analysis, the matter was put one side. The material analyzed consisted of glassy white crystal fragments of specific gravity between 2·965 and 2·989.

I. Analysis of cuspidine, C. H. Warren, 1899.

II. Same recast and recalculated to 100 per cent after substituting equivalents of Ca for Mn, K, and Na.

	I		II	Molecular Ratio		
SiO_2	32·36	Si	15·10	·539		1
CaO	61·37	Ca	44·63	1·115		2·05
MnO	0·71	F_2	9·05	·238	2·189	4·06
Na_2O	0·48	O	31·22	1·951		
K_2O	0·27					
F	9·05					
	104·24					
Less O = F_2	3·81					
	100·43					

The ratio Ca : Si : $(O+F_2)$ = 2 : 1 : 4 very nearly, leading to the formula $Ca_2Si(O, F_2)_4$. This is the formula suggested by Dana (System, 529) for cuspidine, in which fluorine is treated as replacing oxygen. No other treatment of the analytical data gave a satisfactory ratio. It is much to be regretted that no further material remains for more complete physical determination of this interesting species.

Humite: Crystal Form.

Minerals of the humite group have long been known from Franklin under the name of chondrodite. They have not been analyzed nor till recently have good crystals been found. In 1906 were found orthorhombic crystals of deep orange-red and pale yellow color which yielded contact measurements accurate enough to prove the material to be humite.

Forms : b (010), o_2 (210), m (110), e_δ (102), n_a(112), r_4 (214).

Combinations:

1. b, o_2 n_a, r_4.
2. b, o_2, e_δ, n_a, r_4.
3. b, o_2, m, e_δ, n_a, r_4.

Leucophœnicite: Crystal Form.

Leucophœnicite was described by Penfield, whose material did not permit him to determine the system to which the crystals belong. From its relation in composition to the humite group he believed it to be monoclinic.

Crystals of measurable quality very kindly placed in the writer's hands by Mr. Canfield, furnished data for the determination of system and forms.

System, monoclinic:—Axial ratio : $a : b : c$ = 1·1045: 1 : 2·3155. $\beta = 76^\circ\ 44'$.

Forms :

c (001)
b (010)
a (100)
m (110)
s (120)
e (101)
f (102)
x (103)
r $(\bar{1}01)$
i $(\bar{1}02)$
y $(\bar{1}03)$
o (011)
f (012)
l (121)
n $(\bar{1}21)$
u $(\bar{1}22)$
d (123)
h $(\bar{1}23)$
q $(\bar{1}24)$

The crystals are of epidote habit, elongated parallel to the b-axis, the orthodome zone deeply striated. Crystals are twinned on a face in this zone which was taken as the basal pinacoid, the two individuals frequently interpenetrating. The form series is peculiar and could not be correlated in any way with that of any member of the humite group to which leucophœnicite is related chemically.

The presence at Franklin Furnace or at Stirling Hill of the following minerals, not hitherto recorded, has been established: Marcasite, millerite, pyrrhotite, aurichalcite, hydrozincite, psilomelane, göthite, albite, chlorite, ganophyllite, manganese pectolite, descloizite, anglesite and native silver.

With these additions and the omission of a number of species of the older lists which could not be verified, the number of minerals recorded for this locality becomes ninety-three.

Harvard University, October, 1909.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Formation of Colloidal Solutions by the Action of Ultraviolet light upon Metals.*—It was observed by Lenard and Wolf in 1889 that certain substances, particularly metals, were resolved to dust by the action of ultra-violet light. This effect was detected both by the roughening of the surfaces and the detection of the detached particles in the adjacent layers of air. It was found that different metals gave different degrees of this action, that the electrical condition of the metallic plate exerted a pronounced influence upon the action, as did also the nature of the source of light employed. These investigators did not attempt the preparation of colloidal solutions by this means, but they observed, when experimenting with a zinc plate, that a layer of water held back the zinc dust. Svedberg has now made use of this phenomenon in preparing colloidal solutions of various metals in various liquids. He placed the metal, the surface of which must be freed from layers of oxide, in a shallow dish, placed the liquid upon it, and exposed it to the rays of a Heraeus' quartz-mercury arc lamp at a distance of a few centimeters. After a few minutes the liquid when examined by the ultra-microscope showed the characteristic appearance of a colloidal solution. Different metals and different liquids behaved very differently. Silver, copper, tin and lead gave colloidal solutions easily, while platinum, aluminium and cadmium showed little or no effect. The action with lead was particularly strong. When water was used this metal gave a milky liquid in five minutes, probably colloidal hydroxide, while with ethyl alcohol the same metal gave a colloidal metallic solution. Further experiments with lead and silver in water and six different organic liquids indicated that

the size of the particles is very different in the various cases, and that this depends upon the nature of the liquid employed. It was especially interesting to find that it was possible to produce solutions with particles of very small, uniform size which displayed the Brownian movements in a very lively manner. Further study of this matter, which the author is undertaking, promises to be of great interest, and he suggests that it may be of importance in explaining the mechanism of common photochemical reactions.—*Berichte*, xlii, 4377. H. L. W.

2. *Potassium Percarbonate.*—Much uncertainty has arisen in regard to the true constitution of the product prepared in 1897 by Constam and von Hansen by the electrolysis of concentrated potassium carbonate solutions to which the percarbonate formula, $K_2C_2O_6$, was ascribed by the discoverers. Up to the present time this product has always been obtained in an impure condition, containing carbonate, bicarbonate and water, and since it yields hydrogen peroxide and potassium carbonate when dissolved in water, it has been possible to regard it as potassium carbonate with hydrogen peroxide of crystallization, instead of a true percarbonate. Moreover Tantar has obtained a well crystallized product by the combination of sodium carbonate and hydrogen peroxide, to which he gave the formula $Na_2CO_4 + \frac{1}{2}H_2O_2 + H_2O$, regarding it as a percarbonate combined with both hydrogen peroxide and water.

RIESENFELD and REINHOLD have now succeeded in preparing the electrolytic product in a nearly pure anhydrous condition by the use of special precautions. The absence of hydrogen in this preparation proved that it was not a hydrogen peroxide addition product and analyses confirmed the formula $K_2C_2O_6$. They have also found a means for distinguishing between percarbonate and hydrogen peroxide in the fact that the former liberates iodine immediately from a neutral potassium iodide solution, while hydrogen peroxide acts only slowly upon such a solution. By means of this reaction they found that Tantar's product contains no percarbonate, so that its formula should be given as $Na_2CO_3 + 1\frac{1}{2}H_2O_2$.—*Berichte*, xlii, 4377. H. L. W.

3. *A Practical Application of Radium.*—In connection with a research on a revision of the atomic weights of iodine and silver, BAXTER and TILLEY found it necessary to determine small quantities of water in the iodine pentoxide which they were analyzing. This water was absorbed and weighed in glass U-tubes containing phosphorus pentoxide. The usual difficulty in weighing glass apparatus, due to electrical disturbance from wiping it, was avoided here by placing in the balance a few milligrams of radium bromide of radio-activity 10·000 to dispel electrical charges. Under these conditions no difficulty was experienced in weighing the tubes within a few hundredths of a milligram, since they quickly came to constancy in the balance case and retained their weights unchanged for days at a time.—*Jour. Amer. Chem. Soc.*, xxxi, 212. H. L. W.

4. *Volumetric Determination of Selenious Acid.*—L. MARINO has devised a method for this purpose which he prefers to those previously in use. The solution of the selenious acid is made slightly alkaline with sodium hydroxide solution, then a specially prepared alkaline permanganate solution is added gradually, until after heating to boiling a strong violet color is permanent for 4 or 5 minutes. After cooling somewhat the liquid is acidified with dilute sulphuric acid, and an oxalic solution is run in until all the manganese dioxide has dissolved. Then, finally, the excess of oxalic acid is titrated with the permanganate solution. The test-analyses given show very satisfactory results. A special method is given for the removal of nitrates in order that this method may be applied.—*Zeitschr. Anorgan. Chem.*, lxv, 32. H. L. W.

5. *A Contract for Radium.*—It is stated on the authority of the London Times that a contract has recently been entered into between the British Metalliferous Mines (Limited) and Lord Iveagh and Sir Ernest Cassel for the supply of 7½ grams of pure radium bromide at the rate of four pounds per milligram (total about $150,000). The source is pitchblende from the company's mine in Cornwall. This radium bromide is to be presented by Lord Iveagh and Sir Ernest Cassel to the Radium Institute, which will be under the direction of Sir Frederick Treves, for use in the treatment of cancer.—*Chem. News*, xci, 303. H. L. W.

6. *Absolute Measurement of High Pressure with the Amagat Manometer.*—PETER PAUL KOCH and ERNST WAGNER have described in a previous paper a method of measuring accurately high pressures which gave very satisfactory results; but in order to reach a higher degree of exactness they concluded to measure the pressures directly by a height of mercury. The tower of the Laboratory in Munich afforded a height of 25^{m}, and they describe the arrangement of steel tubes by means of which they contained the mercury. A comparison is given of the results of the Amagat manometer, with the results obtained by direct measures, obtained from the height of the mercury column. A constant of correction is given.—*Ann. der Physik*, 1910, No. 1, pp. 31–50. J. T.

7. *A Relation Between Absorption and Phosphorescence.*—The observations of M. G. Lecoq de Boisfaudran and M. G. Urban show that the best known phosphorescent bodies result from a *phosphorogène* in a solvent or diluent. M. L. BRÜNINGHAUS points out a very simple relation between absorption and phosphorescence. The light emanating from the *phosphorogène* molecules situated in the depths of the medium suffer absorption by the superficial layers, and the radiations observed at the surface are only those for which the *phosphorogène* is relatively transparent.—*Comptes Rendus*, Dec. 13, 1909, pp. 1124–1129. J. T.

8. *Mass of Moving Electrons.*—The new theories of electrons are concerned with hypotheses of change of mass with velocity.

Abraham supposes electrons unchanged by velocity, while the Lorentz-Einstein theory is based upon the relativity principle. E. HUPKA in his investigation endeavors to decide which theory is the most probable. The article is interesting principally from the view of technic : for the author describes minutely the method by means of which he excited electron streams in high vacua. Although he did not attain to the velocity of the β ray, he succeeded in producing rays of great homogeneity, suitable for measurement. The vacua were produced by liquid air and the use of charcoal, and he used potentials as high as 90,000 volts. The paper contains many tables and plotted charts, giving comparisons of results on the Abraham or solid sphere theory and the Lorentz-Einstein relativity principle. The measurements agree better with the latter theory than with the sphere theory of Abraham.—*Ann. der Physik*, 1910, No. 1, pp. 169–204.

J. T.

9. *Hertz's Photoelectric Effect.*—M. EUGÈNE BLOCH criticizes the conclusion that this effect coincides in greatness with the Volta series, the metals, more photoelectric, being the more electropositive, and believes that the order can be reversed when one passes from one wave length to another.—*Comptes Rendus*, Dec. 13, 1909, p. 1110.

J. T.

10. *Influence of Thunder on Size of Raindrops.*—V. J. LAINE has studied the changes in rainbows which apparently follow peals of thunder. He describes as follows a typical case : Between six o'clock and five o'clock in the evening he observed in the East a rainbow accompanied by a secondary bow. During thunder the colors of both bows trembled to such a degree that the color limits and the edges of the bows were entirely weakened, and one observed very quick vibrations over the entire rainbow. This occurred with each peal of thunder. The change in color Laine attributes to changes in size of raindrops. The size before peals of thunder was under $0 \cdot 1^{mm}$, and during the thunder it increased to $0 \cdot 5^{mm}$ and to 1^{mm}. The author attributes the change to the acoustical vibration of the thunder.—*Physikal. Zeitschrift*, Dec. 1, 1909, pp. 965–967.

J. T.

11. *Conduction of Electricity through Gases and Radioactivity ;* by R. K. McCLUNG. Pp xvi + 245. Philadelphia, 1909. (P. Blakiston's Son & Co.)—This is a "text-book with experiments" designed to introduce college classes to the fascinating and important subjects indicated by the title. There has been so great a development during the past twelve years in our knowledge of the ionization of gases and the properties of the newly discovered radiations that ample material exists for an interesting and instructive course for students. The present book is the first to be written with this end in view, and it seems well adapted to the purpose. The descriptive portions though very concise are fairly satisfactory and many useful directions are given for performing experiments in this field.

H. A. B.

12. *Die Strahlen der positiven Elektrizität;* von E. GEHRCKE. Pp. xi + 124. Leipzig, 1909. (S. Hirzel.)—This is an excellent and timely account of a class of radiations which have of late years come to be of great importance in physics. The rays which consist of positively charged particles include the canal rays discovered many years ago by Goldstein, certain other rays which are observed in ordinary vacuum tubes, the α-rays from radioactive substances and the "anode rays" (recently discovered by Gehrcke and Reichenheim), which are given out by anodes consisting of the salts of various metals. The properties of all these rays and their accompanying phenomena are described in detail, and the book forms a very useful collection of data upon an important subject. H. A. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey, Thirtieth Annual Report, 1908–1909, of the Director,* GEORGE O. SMITH. Pp. 128, with two plates.—This report contains a statement of the work done by the various divisions of the Survey during the fiscal year ending June 30, 1909. Besides the progress in geologic investigations and topographic mapping, for which the Survey was initially organized, the special lines of work which Congress has delegated to it are worthy of note. The classification of public lands has been carried forward with great activity, resulting in a proper valuation of land according to the use for which it is most valuable. As a consequence the government is deriving a revenue from the sale or lease of said lands many times greater than the cost of the surveys. Fraudulent entries are made more difficult and monopolistic control is prevented, but immediate utilization is fostered; the present system resulting in the greatest good to the nation at large.

The division of mine accidents has been organized within the year, studies have been carried on in Europe and in this country and already large results begin to show toward the prevention of the destruction of both human life and mineral resources.

The technologic branch by its investigations of materials used in government contracts has, during the year, guarded the expenditure of tens of millions of dollars and saved millons to the government.

Because these additions to the work of the Survey are so immediately important and popularly recognized as of great value, conscious effort should be maintained to prevent their encroachment upon the equally valuable purely scientific work upon which such developments ultimately rest. That Congress does not fully appreciate this broader view is shown by the fact that the Survey was only granted $100,000 for stream measurements, whereas $250,000 was appropriated for testing fuels. For topographic surveys $300,000 was appropriated, for geologic surveys $200,000, as during the previous year. The entire appropiation for the year was $1,590,680. J. B.

2. *Fifth Biennial Report. State Geological Survey of North Dakota;* A. G. LEONARD, State Geologist. Pp. 278, plates xxx. Bismarck, North Dakota.—The purposes of the reports of the survey are educational in the teaching of physical geography and elementary geology, and developmental of the economic resources of the state. In this volume, besides the administrative report, there are papers on the geology of southwestern North Dakota with special reference to the coal, by A. G. Leonard; the geology of northeastern North Dakota with special reference to cement materials, by John G. Barry and V. J. Melsted; the geological history of North Dakota, by A. G. Leonard; the Bottineau gas field, by John G. Barry, and a paper on good roads and road materials, by W. H. Clark. The papers in general meet well the purposes for which they are planned and the survey by such a report demonstrates its value to the state. The paper on the geological history of North Dakota could, however, have been improved in a number of particulars.

It was prepared for the use of schools and the general reader, yet there is no statement in it of the fundamental conception that geologic time embraces tens of millions of years. Yet without such discussion the general reader is apt to preserve the inherited notion that time is antediluvian and postdiluvian and the whole embraced in some thousands of years. This, however, is a minor point in comparison with definite errors retained from an earlier period in geology. For example, it is sweepingly stated that "granites are examples of Archean rocks." Whereas they are now known to occur as massive intrusive rocks of any age up to middle Tertiary. Further, it is stated "that the oldest part of the continent, that which was the first to be raised above the sea, was a U-shaped land mass, the two arms of the U enclosing Hudson Bay. At the beginning of the Paleozoic Era by far the greater part of our continent, with the exception of the above land, was beneath the sea." This statement may be compared with Walcott's well-founded conclusions, published in 1891, that the area of the pre-Cambrian Algonkian continent was larger than at any succeeding period until the Mesozoic, and that the Cambrian sea did not begin to invade the great interior continental area until late Middle Cambrian time. It is true that these and other important conceptions have not been properly emphasized in many text-books, but that cannot be regarded as good reason for their further perpetuation. Their importance in geologic theory is, furthermore, such as to warrant calling attention to their occurrence in this report. The idea, however, of publishing in state reports popular expositions of geologic structure and history, as is here done, is a most valuable one from the educational point of view, and one which state surveys have largely neglected. J. B.

3. *The Figure of the Earth and Isostacy from Measurements in the United States;* by JOHN F. HAYFORD, Inspector of Geodetic Work, and Chief, Computing Division Coast and Geodetic Survey. Pp. 178, plates and figures 17. Washington, 1909.—This report is one of great interest to geodesists and geologists, for though the principal conclusions have been previously published by Hayford, this is the first appearance of the complete work. The author points out that earlier computations upon the elements of the spheroid have regarded the deflections of the vertical as accidental errors, an assumption which is evidently untrue. By considering them as due to the known irregularities in topography largely counterbalanced by the unknown irregularities in subsurface densities, a solution is reached giving the character of the latter, and by thus allowing for constant errors attaining more correct and larger values for the dimensions of the spheroid. By assuming in the solution the existence of certain deficiencies of mass underlying elevated tracts, the weight of the new determination of the terrestrial dimensions becomes 1·7 times that derived otherwise. This may be taken as a mathematical demonstration of isostacy. Hayford furthermore finds that isostatic adjustment is so nearly complete that the deflections of the vertical average are less than a tenth of what they would be if due to topographic irregularities alone and the stress differences in the crust are not more then one-twentieth what they would be if isostacy did not prevail. Consequently the United States is not maintained in its position above sea level by terrestrial rigidity but is in the main buoyed up, floated, in each of its parts, because it is composed of material of deficient but irregular density. The solution further shows that the flotation is not due to a lighter crust resting upon a fluid and denser substratum and that the isostatic compensation is approximately satisfied within a hundred miles of the surface. This report brings forth the results of a monumental labor and its author and the organization which he represents are to be congratulated upon its completion. The results will be most interesting if gravity determinations are now made in order to throw further light upon the variations in subsurface densities extending to the depth at which isostatic compensation becomes complete.

The reviewer would point out that the conclusion, that the various physiographic provinces are now so closely compensated that the unbalanced stresses in the earth are not more than a twentieth as great as they would be if isostatic adjustment did not prevail, is seemingly at variance with the geological evidence that the crust is able to remain unwarped during long periods ot time, permitting the wide development of base-leveled surfaces. The reconciliation of these two well-founded conclusions of modern geology is one of the larger problems awaiting solution in the future. Although, as Willis has suggested, the present epoch may be one of unusually complete isostatic adjustment, how comes it that if so complete at present, at other times the crust could for so long have resisted the stresses due to widespread erosion? J. B.

4. *Geological Survey, Cape of Good Hope;* by A. W. ROGERS, Director; 13th Annual Report, Cape Town, 1908.—The 1908 Report of the Geological Commission contains the following papers: (1) Report on the Geology of parts of Prieska, Hay, Britstown, Carnarvon and Victoria West, by A. W. Rogers and A. L. du Toit; pp. 9–109, figs. 13; (2) The kimberlite and allied pipes and fissures in Prieska, Britstown, Victoria West and Carnavon, by A. L. du Toit; pp. 111–127, 3 figs.; (3) Notes on a journey to Knysna, by A. W. Rogers; pp. 129–134, 1 plan.; (4) The Tygerberg anticline in Prince Albert, by A. W. Rogers; pp. 135–139. Field work in Prieska and adjoining regions included a study of areas previously mapped, with the result that errors were found to have been made in the determination of structural and stratigraphic relations. This present report, therefore, replaces in large part the report for 1899. (This Journal, xiii, 413.) New occurrences of Dwyka beds are described and petrographic studies have been made of a number of igneous and metamorphic rocks including an unusually large variety of granulites, the origin of which is in doubt. An interesting economic feature is the fact that the water supply is found in decomposed dikes of kimberlite, etc., rather than in the shales and other sedimentaries. H. E. G.

5. *The Devonian fauna of the Ouray limestone;* by E. M. KINDLE. Bull. 391, U. S. Geol. Survey, 1909; pp. 60, plates 10.—This Upper Devonic fauna characterized by *Plethorhyncha endlichi* and *Spirifer* cf. *whitneyi* is now known to extend from southern New Mexico to the north line of Colorado. It is composed of 40 species, most of which are restricted to this biota. The strikingly new element is a brachiopod related to *Syringothyris*, for which is here proposed the new generic name *Syringospira.*

The author does well in removing for western faunas the name *Spirifer disjunctus*, but he should have gone a step farther and renamed the so-called *S. whitneyi*, as these Colorado shells are not identical with the typical Iowa individuals. The reviewer has seen the Ouray species also in the Three Forks of Montana and in British Columbia north of the Canadian Pacific Railway. C. S.

6. *Lower Paleozoic Hyolithidæ from Girvan;* by F. R. COWPER REED. Trans. Royal Soc. Edinburgh, 47, 1909; pp. 203–222, pls. 3.—From the Ordovician and Silurian beds of the Girvan district the author describes 10 new species of Hyolithes, 4 Orthotheca, 2 Ceratotheca, and 5 Pterotheca. C. S.

7. *Die asiatischen Fusulinen. Die Fusulinen von Darwas;* von GÜNTER DYHRENFURTH. Palæontographica, Band 56, 1909, pp. 137–176, pls. 13–16.—In this work, which is a continuation of Ernst Schellwien's contemplated Monographie der Fusulinen, are described with great care six forms of Fusulina illustrated by many microphotographs. The geologic occurrence is also fully given. C. S.

8. *Paläozoische Seesterne Deutschlands. I. Die echten Asteriden der rheinischen Grauwacke;* FRIEDRICH SCHÖNDORF, Palæontographica, 56, 1909, pp. 38–112, pls. 6–11.—Here are described in detail 12 species of Lower Devonic starfishes of the family Xenasteridæ. These are grouped in the genera *Xenaster* (4 species), *Spaniaster* (1), *Agalmaster* n. gen. (3), *Rhenaster* n. gen. (1), *Trimeraster* n. gen. (1), *Eifelaster* n. gen. (1), and *Asterias.* The drawings are somewhat diagrammatic but illustrate the characters far better than would photographs.

In all the genera the ambulacrals are directly opposite one another and do not alternate. The ambulacrals and adambulacrals are also opposite each other. The mouth opening is bounded by 5 pairs of mouth plates and 5 pairs of slightly modified ambulacrals. No ocular plates are preserved, according to the author; the reviewer has seen none in these old starfishes before the time of the Lower Cariboniferous. C. S.

9. *La Vallée de Binn (Valais). Étude géographique, géologique, minéralogique et pittoresque;* par LÉON DESBUISSONS. Pp. viii, 324; 51 illustrations, etc. Lausanne, 1909 (G. Bridel & Co.).—This is a popular work on a mineralogical locality which occupies a unique position in the interest of the occurrence and the almost inexhaustible variety of new and rare species which it has afforded. These facts are briefly summarized here, and many illustrations give an admirable idea of the scenery of the valley.

10. *Catalogue of the Fossil Bryozoa in the Department of Geology, British Museum of Natural History.* The Cretaceous Bryozoa, Volume II; by J. W. GREGORY. Pp. xlviii, 346, 9 plates, 75 figures.—The first volume of this catalogue was published in 1899 and the appearance of the present volume has been delayed in consequence of the retirement of the author from the staff of the British Museum. In the years which have intervened a large amount of material has been added to the collections of the Museum, so that the whole work has been expanded and when complete will embrace a third concluding volume. It is expected that this will be shortly prepared by Mr. W. D. Lang, who succeeded Dr. Gregory as Assistant in charge of this section of the Museum.

11. *A Hand-List of the Genera and Species of Birds [Nomenclator Avium tum Fossilium tum Viventium];* by R. BOWDLER SHARPE. Volume V. Pp. xx, 694.—This volume of the British Museum Handlist of Birds deserves to be especially noted, since it completes a large and most important labor begun in 1898. The author and those who have worked with him deserve the congratulations of zoologists for what they have done in this way to advance the study of ornithology.

12. *Physiologische Pflanzen-Anatomie;* von Dr. G. HABERLANDT. Pp. xviii, 650. Vierte Auflage. Leipzig, 1909 (Wilhelm Engelmann).—This is the fourth and enlarged revision of a very important work. A quarter of a century has passed since Professor Haberlandt, then as now at Graz, published the first

edition. The treatise was recognized from the outset as opening up fresh fields of research on the borders between three allied departments of Botany. The relations which exist between form, function, and origin are sometimes exceedingly obscure, and this obscurity was deepened in many instances by the neglect of some gross morphologists to investigate the minute anatomy of the organs in question. To Schwendener and Haberlandt is due a large part of the credit for stimulating observers to enter upon this middle ground in the right way. The present volume by Haberlandt is in many respects a great improvement upon the previous editions, since it enters more boldly upon the field of œcology and brings up some of the very attractive questions in the domain of what we may term applied physiology. It is truly surprising to notice the small number of changes in the statement of facts which the author has been compelled to make in the period of twenty-five years. The extreme caution which characterized the early edition has borne good fruit in the later ones, since there have been practically no mistakes to recall. The treatise in its enlarged form is of great value to morphologists, anatomists, and œcologists, and, in a general way, to systematists, as well.

The publisher has wisely reprinted as a separate, the pages devoted to the irritable organs of plants, since the subject of sensitiveness is attracting at the present time a good deal of attention. A few physiologists will not agree with some of Haberlandt's conclusions, but even they must admit his fairness and clearness. G. L. G.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of the Secretary of the Smithsonian Institution*, Dr. CHARLES D. WALCOTT, *for the year ending June 30, 1909.* Pp. 95.—The annual report of the Secretary of the Smithsonian Institution for the year ending June, 1909, has recently appeared. It gives the usual interesting summary in regard to the activity of the Institution in its varied functions. Dr. Walcott draws attention to the fact that in the estimates for the present year there is an increase of $10,000 for the Bureau of Ethnology, to be used in connection with researches among the tribes of the Middle West and also in Hawaii and Samoa. A larger appropriation is also called for to carry on the work of the Astrophysical Observatory, for the Zoological Park, and particularly for the new building of the National Museum, which is now nearing completion. In regard to the latter it is stated that the entire stone work of the outer walls is completed, as also the roofs and skylights, and much progress has been made in the interior, that it was expected that some of the halls and work-rooms would be ready for use early in the autumn (1909). The International Tuberculosis Congress, in the autumn of 1908, utilized

for its meetings and exhibitions a large part of the first and second floors. A full statement in regard to the National Museum as a whole is given by Dr. Rathbun in the volume noted below.

A brief summary is given of the first accessions to the Museum from the Roosevelt expedition in Africa. The results have been even more important than anticipated, including many excellent specimens, particularly of the skins of the larger mammals. Special funds were provided by friends of the Institution to pay for the outfit and expenses of the naturalists who accompanied Col. Roosevelt, while his own expenses, with those of his son, have been met by himself. Mr. W. W. McMillan of Juja farm near Nairobi, East Africa, has presented an exceptionally fine collection of living African animals.

Of other scientific work carried out under the auspices of the Institution may be mentioned the continued explorations by the Secretary, Dr. Walcott, in Montana and the Canadian Rockies, having as their object the study of Cambrian geology and paleontology. Professor J. P. Iddings is now carrying on researches on a Smithsonian grant in Japan, Eastern China, and Java. Miss Alice Eastwood, also as the result of a grant, has re-collected the botanical species from the region of Santa Barbara secured by Thomas Nuttall in 1836. Under the Hodgkins fund several investigations have been prosecuted. The statements in regard to the Library, the Gallery of Art, the Zoological Park, etc., are all interesting, but cannot be summarized here. As usual, Mr. C. G. Abbott, director of the Astrophysical Observatory, gives a summary of the work carried on under his direction at Washington, at Mt. Wilson, and on Mt. Whitney.

2. ***Annual Report of the Board of Regents of the Smithsonian Institution, showing the Operations, Expenditures, and Condition of the Institution for the Year ending June 30, 1908.*** Pp. x, 801, with 23 plates, 25 figures, and 4 charts.—The Secretary's Report, which forms the opening portion of this volume, was noticed a year since (see vol. xxvii, p. 196). The general Appendix (pp. 113–801) contains as usual a large series of papers on scientific subjects, covering many lines of scientific activity and discovery. No more well-selected and useful presentation of recent scientific memoirs, in a form to interest the intelligent public, can be found in a single volume. The opening paper is devoted to aeronautics and is profusely illustrated; aviation in France and wireless telephony follows, then phototelegraphy, and the gramophone; while on the Natural History side we find reproduced (from this Journal, xxv, 169) the important paper by Dr. Lull on the Evolution of the Elephant, with another on Angler Fishes by Dr. Gill. The volume closes with several biographical papers.

Recent publications from the Smithsonian Institution are noted in the following list:

Report on the Progress and Condition of the U. S. National Museum for the year ending June 30, 1909. Pp. 141.—This is a full and very interesting account of the Museum, its buildings, collections, and library, by Dr. Richard Rathbun, Assistant Secretary of the Smithsonian Institution.

The National Gallery of Art: Department of Fine Arts of the National Museum; by Richard Rathbun. Pp. 140, 26 plates.—Dr. Rathbun has given here a full history of the development of the department of Fine Arts in the National Museum, begun in 1840. The bequest of Mrs. Harriet Lane Johnston in 1903 and the gift of Mr. Charles L. Freer of Detroit have given the National Gallery a notable position in the country; a suitable building for its preservation must be provided later. The concluding chapter of this volume gives a preliminary catalogue of the collection with numerous reproductions of important pictures.

Bureau of American Ethnology, Bulletin 38. Unwritten Literature of Hawaii. The Sacred Songs of the Hula; collected and translated, with notes and an account of the Hula; by Nathaniel B. Emerson. Pp. 288, 24 plates, 3 figures.

Bulletin 39. Tlingit Myths and Texts; recorded by John R. Swanton. Pp. viii, 451.

Bulletin 41. Antiquities of the Mesa Verde National Park: Spruce-Tree House; by Jesse Walter Fewkes. Pp. 57, 21 plates, 37 figures. Washington, 1909.

Bulletin 42. Tuberculosis among certain Indian Tribes of the United States; by Ales Hrdlicka. Pp. vii, 48, 22 plates.

3. *National Antarctic Expedition, 1901–1904. Magnetic Observations.* Prepared under the Superintendence of the Royal Society. Pp. vii, 274; 13 figures, and 43 plates, map and sketches. London, 1909.—The earlier volumes containing the records of the Antarctic Expedition of 1901–1904, under Captain R. F. Scott, R. N., have already been noticed in this Journal (xxvi, 588; xxvii, 271); that on Physical Observations included a report on a portion of the magnetic work. The present volume completes this subject, giving detailed tables of hourly values of the magnetic elements with an exhaustive discussion of the same. Dr. Charles Chree of the Kew Observatory has taken an important part in the elaboration of the observations.

Among the special topics discussed may be mentioned a comparison of Antarctic disturbances and the aurora, and also an examination of disturbances simultaneous in the Antarctic and Arctic, from October, 1902, to March, 1903, by Prof. Kr. Birkeland. The sketch map which forms the frontispiece shows a portion of the coast of South Victoria land with the winter quarters of the "Discovery" on Ross Island. On it are noted the positions of the south magnetic pole as given by three successive recent expeditions. The close agreement between these, the distance varying from a maximum of about 80 miles to a minimum of about 40 miles, is particularly noteworthy. The latitude and longitude of these three positions are as follows:

Position found by the "Southern Cross,"	Lat. 72° 40′ S	Long. 152° 30′ E
" " " " "Discovery,"	72° 51′	156° 25′
" " " Lieut. Shackelton,	72° 25′	155° 16′

4. *The Evolution of Worlds;* by PERCIVAL LOWELL. Pp. xiii, 262. New York (The Macmillan Co.).—This book is a revised edition of lectures delivered in February and March, 1909, before the Massachusetts Institute of Technology, in which institution the author is non-resident professor of astronomy. The lectures present the most recent facts and speculations regarding the past and future of the Solar system, illumined by the play of the author's active imagination and colored by an astonishing vividness of language. We do not remember to have met in any of Dr. Lowell's previous essays any such freedom in the use of English. Some of the theories which he explains are startling, but the language in which they are set forth is much more so. If we all permitted ourselves such liberties with our mother tongue it would speedily descend to a chaos and darkness such as Dr. Lowell predicts for the solar system itself.

We quote at random from the first few pages.

"Unimpressing our senses," "grandiose vicissitudes spectrally revealed," "stars cuticle," "ambidextrous impartiality of space," "The culmination of Coalition"—"the acme of accretion."

But such mishandling of language, though it irritates the reader and mars his enjoyment, does not vitiate the logic or destroy the substance of the book.

The first two chapters, entitled "Birth of a Solar System," and "Evidences of the Initial Catastrophy," will excite most interest. The author considers that the initial stage of our solar system, or rather the beginning of the cycle of change through which it is now passing, was that of a spiral nebula. From this the present order arose and to it in some distant age and region it may again return, to repeat the cycle indefinitely. Such an enormous program, which explains everything but the origin of matter and provides for its eternal activity, satisfies the mind and makes us wishful that it may be true.

Space forbids a discussion of it further than to say that the spiral form in a nebula is held to be due to action from without rather than from within, in fact to a tidal disruption caused by the passage of a large body close to the previously quiescent mass. Thus an old and worn out sun may be torn up within a few days into a meteoric nebula, heated by collisions of its fragments and developing under gravity into a planetary system.

W. B.

5. *Hyperbolic Functions,* prepared by GEORGE F. BECKER and C. E. VAN ORSTRAND. Pp. li, 321. Smithsonian Mathematical Tables, No. 1871. Washington, 1909.—In the systematic study of mathematics hyperbolic functions do not receive the attention which their practical importance as a tool of investigation warrants. Invented or first employed by Mercator in the development of his system of projection, on which to this day all deep sea navigation depends, they have come to play an important part in many branches of applied mathematics. Thus in physics whenever an active entity is extinguished or absorbed (e. g. light, velocity, radio-activity) the decay is represented by some form of

hyperbolic function. Mechanical strains also are most simply expressed in this form. Hence the study of geological deformations always requires the use of these functions; and it is for this reason that the overseers of the U. S. Geological Survey, Messrs. Becker and Van Orstrand, have prepared this most complete and scholarly treatise.

The book has a two-fold value. The tables, eight in number, furnish everything that a worker with hyperbolic functions can need, and they are preceded by an admirable exposition of the theory of hyperbolic function. The subject is developed both from an analytic and independently from a geometrical basis and the relation to elliptic functions is described and also the connection with the geometry of the pseudo sphere. An historical sketch adds greatly to the breadth of view of the subject and fifteen pages are given to formulas which the writers designate as "those most likely to be needed by computers."

This description should make it evident that the book furnishes the most satisfactory treatise on this subject that has hitherto been published. W. B.

6. *Robbins's Plane Trigonometry*; by EDWARD R. ROBBINS. 8vo, pp. xiii, 153. New York (American Book Company).—A book well adapted for the secondary school course. It represents the experience of a mature and careful teacher whose first object is to get the essentials of the subject into the head of the average boy as quickly and firmly as possible. The learner is introduced to the solution of trigomometric equations sooner than usual, in fact in the first chapter, but the treatment of identities is postponed until quite late for the reason that the author aims to give his followers strength and courage for the assault of this formidable enemy of the weak trigonometer. The distinction between an identity and an equation, however, is not explicitly stated.

W. B.

7. *Experimental Dairy Bacteriology*; by H. L. RUSSELL and E. G. HASTINGS. 147 pages; illustrated. Boston 1909 (Ginn and Co.).—The purpose of this book is to present an elementary course in general dairy bacteriology. Though brief and somewhat limited in its scope, it is complete in itself. The sources of milk contamination, the biological changes that take place in milk, with methods of identifying milk bacteria, the preservation of milk, butter-making, cheese, and milk as a vehicle of disease, are some of the important topics discussed. A thorough mastery of the book should enable the student to pursue intelligently more advanced work in connection with the problems of dairy bacteriology or dairy manufactures. L. F. R.

8. *Bref och Skirfvelser af och till Carl von Linné*; af TH. M. FRIES. Pp. iv, 342. Stockholm, 1909.—This third part of the first volume of the correspondence of Linnaeus contains letters Nos. 459 to 573; they are arranged alphabetically, according to the names of the recipient or writer, from A to B. This important publication is being carried on under the auspices of the University of Upsala, and the librarian of the University asks that any persons possessing letters of Linnaeus communicate with him on the subject.

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VOL. XXIX. MARCH, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES

VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

No. 171—MARCH, 1910.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union; $6.25 to Canada. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

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Art. XIV.—*The Armor of Stegosaurus;* by Richard S. Lull.

[Contributions from the Paleontological Laboratory of Yale University.]

I. Introductory.
II. Character of armor.
III. Morphology of the plates.
IV. Position of the armor.

I. Introductory.

The American genus *Stegosaurus*, first made known to science by Professor Marsh, includes the most bizarre and grotesque of armored dinosaurs; a group apparently quite apart from the glyptodon-like Ankylosauridæ with heavy mail developed over the entire body, for in *Stegosaurus* the striking armament was confined to certain regions and, so far as our knowledge goes, but little developed elsewhere.

Stegosaurus, while belonging to the Morrison, the beginning of the Lower Cretaceous (Lull, this Journal, vol. xxix, p. 15), was highly specialized and evidently represented a senile race, and was, as Beecher has shown with other spinescent forms, on the verge of extinction, for it shortly disappears entirely from our records.

II. Character of armor.

The known armor of *Stegosaurus* includes five types of structures, all dermal in origin, of which the first are the small, rounded ossicles (gular plates) found *in situ* beneath the skull. These form a continuous, pavement-like investiture protecting the throat (fig. 1) and doubtless extending over a considerable portion of the body as well, though not elsewhere preserved, for it is unreasonable to suppose that an armored reptile would have any portion of the skin bereft of scutes or scales of some sort. These throat ossicles increase in size as one goes back-

FIG. 1.

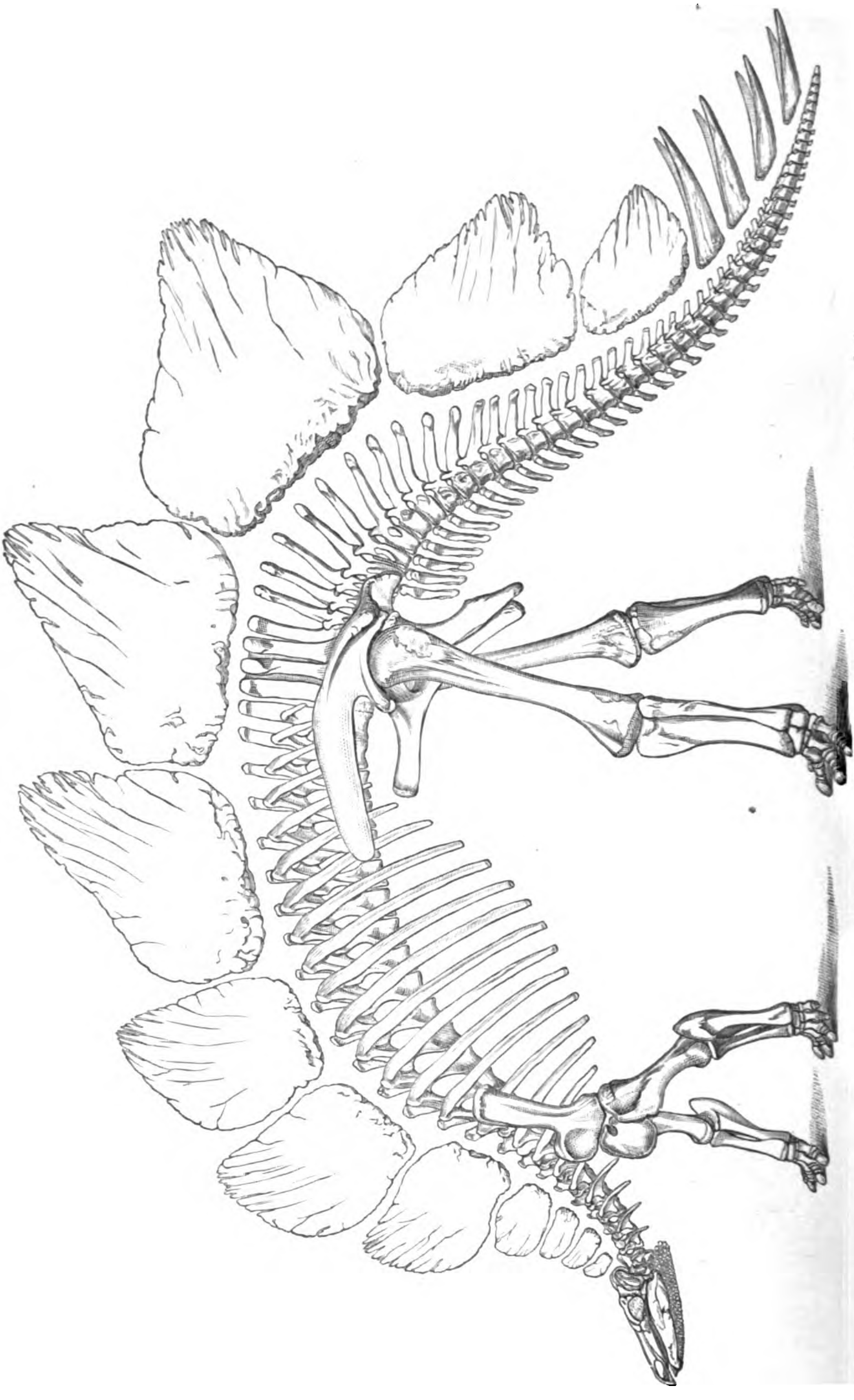

FIG. 1. [illegible] of *Stegosaurus ungulatus*. After Marsh. 1/30 natural size.

ward from the apex of the jaw, the largest of them being not less than 25^{mm} in diameter.

The dorsal armor consists in turn of four distinct shapes, two apparently defensive and two offensive, with a marked differentiation in form as well as in function. Of these the first (fig. 2) are more or less oval, with a base divided longitudinally by a deep cleft so as to be distinctly bifid and of very short fore and aft extent compared with the expanse of the plate. These plates show a very rapid increase in size, though the largest of them in *Stegosaurus ungulatus* is only about half the height and one-third the antero-posterior diameter of the largest of the next type. These bifid based plates seem to have been borne on the neck, the largest oval one here figured (fig. 2) being near the point of junction between the neck and the trunk.

Fig. 2.

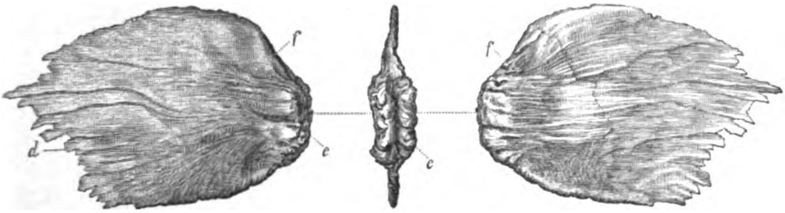

Fig. 2. Cervical plate of *Stegosaurus ungulatus*. After Marsh. 1/12 natural size. *a*, side view; *b*, inferior view of base; *c*, opposite side; *d*, thin margin; *e*, rugons bases; *f* and *f*^{1}, surface marked by vascular grooves.

The second type are the large, thin, rectangular or somewhat triangular plates with a thick base but without the median longitudinal cleft. They doubtless stood in pairs along the trunk region and upon the proximal portion of the tail (fig. 3).

Fig. 3.

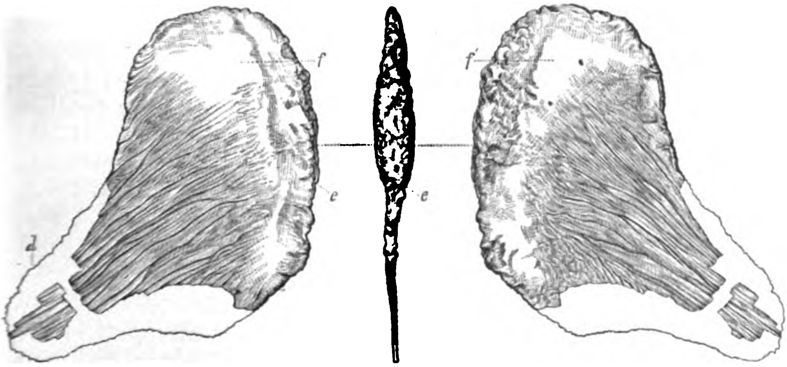

Fig. 3. Dorsal plate of *Stegosaurus ungulatus*. After Marsh. 1/12 natural size. *a*, right side; *b*, thick basal margin; *c*, left side; other letters as in fig. 2.

Stegosaurus ungulatus as represented by the specimen (Cat. No. 1853) now being mounted at Yale was apparently the best endowed with offensive weapons of any of its relatives, for there are associated with the one skeleton no fewer than four pairs of spines and three odd, sharp-edged, spine-like plates, one of which is so much larger than the other two that it seems to imply that at least one intervening size is missing.

The spine-like plates are characterized by a very oblique, flat base, by sharp edges fore and aft and, like the others, by the impression of blood-vessels over the side expanse (fig. 4). In common with the dorsal plates they give evidence of having been deeply imbedded in the integument and underlying connective tissue, but, unlike the latter, they show a better surface for the attachment of muscles to give rigidity to their position.

Fig. 4.

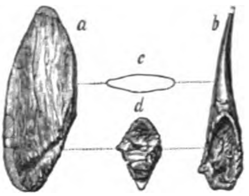

Fig. 5.

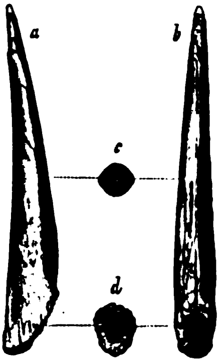

Fig. 4. Caudal spine-plate of *Stegosaurus ungulatus*. After Marsh. 1/12 natural size. *a*, side view; *b*, posterior view; *c*, section; *d*, inferior view of base.

Fig. 5. Caudal spine of *Stegosaurus ungulatus*. After Marsh. 1/12 natural size. *a*, side view; *b*, dorsal view; *c*, section; *d*, inferior view of base.

Of the caudal spines (fig. 5) the anterior ones are the larger and more deeply embedded, being lodged in a thicker portion of the tail, and in common with all of the plates give evidence of having been ensheathed with a close-fitting integument, probably of a horny character as in the modern horned toads (*Phrynosoma*) and in *Moloch horridus*.

III. Morphology of the plates.

Upon comparing a given plate with a scute of a crocodile, or that of such a dinosaur as *Ankylosaurus* or *Stegopelta*, it at once becomes apparent that the great expanse of the first represents merely an enormous hypertrophy of the median ridge or carina of the latter. This expanse is practically alike on both sides, with blood-vessel impressions and no indication that either one side or the other was in contact with the creature's flesh. On the other hand, the base, the morphological equivalent of the body of the scute in crocodile or Ankylosaur, is always somewhat asymmetrical even when divided into two portions by the longitudinal cleft of those of the cervical region. This base in the great dorsal plates particularly is extremely rugous, implying either a heavy pad of cartilage or a very thick connective tissue between the plate and its underlying skeletal support. There is in no instance any indication of a true articulation with the subjacent bones.

FIG. 6.

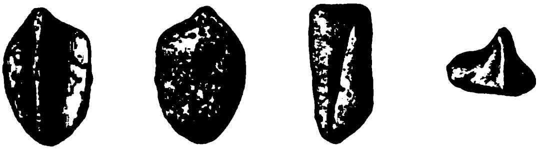

FIG. 6. Dermal plate of *Ankylosaurus*. Figured by Marsh as that of *Triceratops* and showing the median carina. 1/8 natural size.

IV. POSITION OF THE ARMOR.

The position of the armor plates has given rise to an animated discussion as to whether they were in one row or two, opposite or alternating, erect or procumbent. The evidence seems to point to a double row of paired, erect plates, though toward the end of the tail the aggressive series evidently stood out at a decided angle from the perpendicular. It is quite possible that they were provided with an erectile musculature to give them greater rigidity especially in time of use, as is the case with the nasal horn of the rhinoceros. This seems to have been particularly true of the tail.

Professor Marsh (this Journal, xxxiv, 1887, p. 415), who first described and figured the dermal armor of *Stegosaurus*, says: "The upper portion of the neck, back of the skull, was protected by plates *arranged in pairs* [italics mine] on either side. These plates increased in size farther back and thus the trunk was shielded from injury. From the pelvic region backward, a series of huge plates stood upright along the median line, gradually diminishing in size to about the middle of the tail."

In his restoration of *Stegosaurus* (fig. 1), first published in 1891, however, Marsh places the entire series of plates in a single row along the mid-line of neck, back, and tail, although the caudal spines are represented as paired.

Evidence for pairing of the entire series is shown in two specimens preserved in the U. S. National Museum, in one of which the plates alone are represented while in the other they are actually in association with the underlying bones. These plates if placed consecutively would measure twice the length of the neck and back, the proportion being 16 to 8 feet. This evidence, together with the fact that each individual plate as shown above is in itself not symmetrical, indicates that the plates were not median but lateral structures and were arranged in at least two rows.

The first restoration showing the plates in two rows is given in a drawing made by Charles R. Knight under the direction of F. A. Lucas and published by the latter first in his book "Animals of the Past," New York, 1901, fig. 24, and again in the Smithsonian Report for 1901, plate IV. Later, under Mr. Lucas's direction, a model was made by Mr. Knight in which the number of caudal spines was reduced to two pairs and the plates were placed in such a way as to alternate along the back. The reasons given for this arrangement were two-fold: first, that the plates did actually alternate as they lay embedded in the rock, and second, that no two of them were precisely similar in exact shape or dimensions. Against the argument that no known reptile has alternating dermal elements was urged the apparent fact that this did not render it an impossibility in *Stegosaurus*. It seems to me, however, that the position of the plates in the rock is hardly conclusive; for the series of one side might easily have shifted forward or backward slightly during maceration or in the subsequent movement of the rocks, as an oblique crushing of fossil bones is a very familiar phenomenon.

The slight disparity of size and shape in the two plates of a pair is not surprising when one considers that the entire hypertrophy of the plate is in a sense abnormal and is comparable to the growth of the antlers of deer of which those borne by an individual are rarely if ever precisely similar in size, weight, form, or even in number of points. I should consider a *precise matching* of the stegosaur plates remarkable rather than the reverse. The fact that in no other reptile the lateral dermal elements alternate seems too weighty an argument to be lightly dismissed.

The evidence in favor of an erect rather than a procumbent or imbricating position is the morphology of the plate itself, as described above, and the fact that in the crocodile and gavial one can witness the actual hypertrophy of the median keel in the two rows of scutes, which finally merge into one along the mid-dorsal line of the distal half of the tail. The elevation of the keel becomes more and more pronounced beginning with

FIG. 7.

FIG. 8

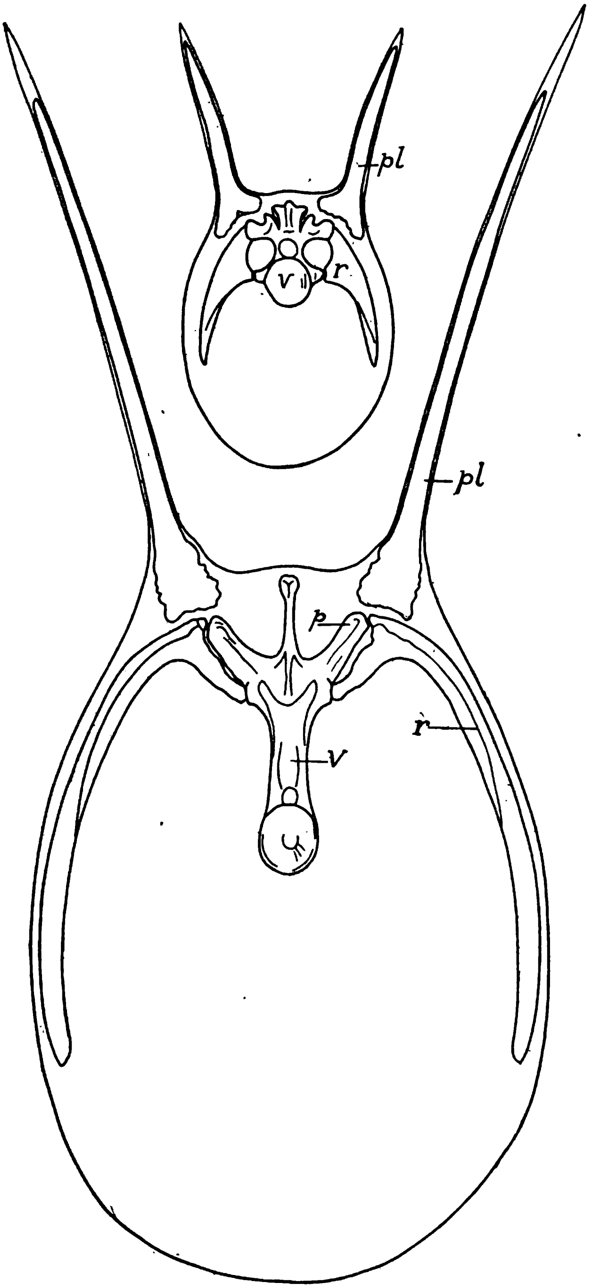

FIG. 7. Section of neck of *Stegosaurus ungulatus*. *pl*, plate; *r*, rib; *v*, vertebrum.

FIG. 8. Section of the trunk of *Stegosaurus ungulatus*. *p*, transverse process; other letters as in fig. 7.

the second quarter of the tail, reaching its maximum where the two rows merge into one and finally dwindling again toward the tip.

In the specimen of *Stegosaurus stenops*, No. 4934 of the National Museum, the last three plates, those over the sacral region, lie as though they had fallen to the right, the anterior ones to the left, a thing manifestly impossible in plates naturally procumbent on either side.

FIG. 9.

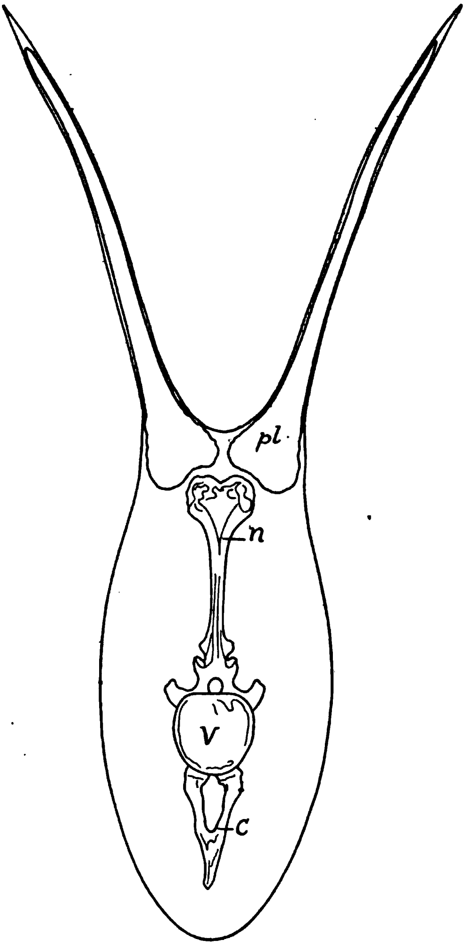

FIG. 9. Section of the proximal part of the tail of *Stegosaurus ungulatus*. *c*, chevron; *n*, neural process; other letters as in fig. 7.

FIG. 10.

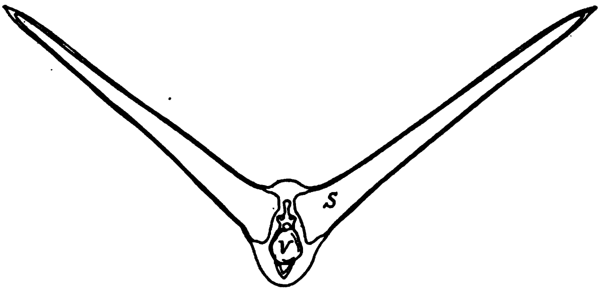

FIG. 10. Section of the distal portion of the tail through the spines. *s*, caudal spine ; other letters as in fig. 7.

The four sections of *Stegosaurus* which I present will show the relationship of the plates to the underlying skeletal elements. The first section (fig. 7), that through the neck, shows the plates with bifid base astride the transverse process of the vertebra, and the second, that through the trunk (fig. 8), the immense broad-based plates borne over the transverse process and ribs. A beautiful mechanical device is shown in that the transverse process is triangular and the rib T-shaped in cross section in the armor-bearing region, giving the maximum of strength, a wide bearing surface and a minimum expenditure of material. The significance of the great elevation of the transverse process is also apparent.

In the sacral and anterior caudal region the bases of the two rows of plates are approximated, and now the summit of the neural process broadens out to support their weight, as indicated in the third section (fig. 9). This broad-topped type of neural process ceases with the proximal third of the tail and indicates the beginning of the flexible aggressive weapon of offense bearing the sharp-edged spine-plates and caudal spines which are inserted obliquely into the muscular mass on either side in the angle formed between the neural process and the centrum (fig. 10).

Some of the larger spines, notably that described by Marsh as the type of *Stegosaurus sulcatus*, have the base divided by an asymmetrically placed longitudinal ridge (fig. 11) into two facets which seem to have borne against the neural process and centrum of the vertebra. This character is only present in very large spines which have a deep insertion into the underlying tissues. Ordinarily the insertion seems to be too shallow to give rise to the facets.

Owen has figured what he calls the "carpal spine" in *Dacentrus (Omosaurus) hastiger* from the Kimmeridgian of Wiltshire (Mon. Brit. Fos. Repts. pl. 77), which shows precisely

FIG. 11.

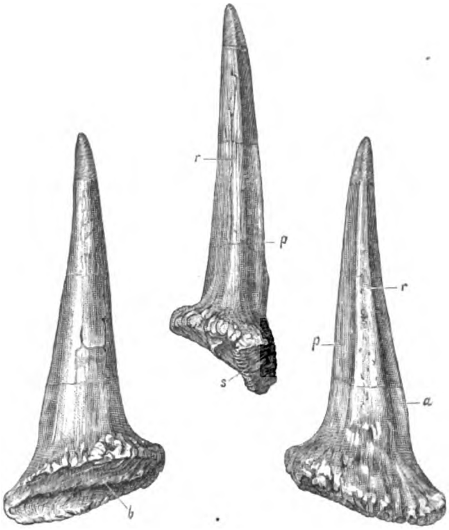

FIG. 11. Caudal spine of *Stegosaurus sulcatus.* After Marsh. 1/12 natural size. Dorsal, anterior and ventral aspects. *b*, the base showing longitudinal ridge.

this same structure of the base as in *Stegosaurus sulcatus.* *Dacentrus* is the probable Old World ancestor of *Stegosaurus*, but while the caudal spines are known, the presence of the armor plates has not as yet been demonstrated.

Art. XV.—*Times of Fall of Meteorites;* by O. C. Farrington.

The times of fall of meteorites may be studied with reference to the year, month, day and hour. The yearly falls should give evidence as to the frequency of the occurrence and exhibit periods if any occur. The falls by months should show the relation of meteorites to well-established star showers and the portion of the earth's orbit where meteorites are most frequently encountered. The falls by days should exhibit periodicity if any exists and variation in the uniformity of supply. Finally, the hours of fall should give the direction of movement of meteorites. Since new falls occur yearly, data for study of these points are obviously constantly on the increase. It is desirable, however, to make comparisons at intervals in order that any changes may be discerned. At the present time the admirable catalogues of Wülfing* and others afford excellent means for the collection of such data. From these catalogues, with such additions and corrections as could be made from other sources, the writer has obtained record of 350 well authenticated meteorite falls of which the year and month are known, 327 of which the day is known, and 268 of which the time of day is known. In this number it has been sought not to include finds referred by residents of a locality to meteors which they had seen a year or more before, since the residents of most localities can, on the occasion of a meteorite find, recall a large meteor seen in that locality at some previous time. To connect this, however, without further reason with the meteorite found seems an unreliable method of procedure.

Considering the falls by years, it is well known that previous to the nineteenth century little reliable record of meteorite falls is available. Single falls are known for the years 1492, 1668, 1715, 1723, 1751, 1766, 1773, 1785, 1787, 1790, 1794, 1795 and 1796, and two falls each for the years 1753, 1768 and 1798. Also for the early part of the nineteenth century the record is not very complete, since during that period the possibility of meteorite falls was yet much doubted. However, the record may as well begin with 1800. From that year to the present, 331 falls may be accepted as well authenticated as to their month and year. During this period eleven years show no falls whatever. These years are—1800, 1801, 1809, 1816, 1817, 1832, 1839, 1888, 1906, 1908, and 1909. Of these the years of the present decade will probably have falls to their credit after a time, since the record of falls usually lags several years behind their occurrence. The largest number of falls shown in any year during the period is 11, in 1868. The years 1865, 1877 and 1886 show 7 each. All the other years show from 1 to 6 falls each. On the whole, therefore, the record seems to indicate a comparatively uniform supply of meteorites, which is the more remarkable when one considers the various chances affecting the observation of their fall. The record seems to afford no evidence of cycles or periodicity which can be traced with certainty. Still the record of years is perhaps not as satisfactory for establishing conclusions in this regard as is that of other periods. As the writer has shown elsewhere,* at least 900 meteorites probably reach the earth yearly. Of these only an average number of 3 is recorded, so that it is evident that a large allowance must be made for unrecorded ones. Yet it is fair to presume that those recorded are typical of the whole, because while opportunities for observation of meteorite falls have probably continually increased in number since 1800, the record by decades shows that the decade from 1860 to 1870 considerably exceeded in number of falls either of the two succeeding ones.

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* **Die Meteoriten in Sammlungen, Tubingen, 1897.**

Passing from the falls by years, the falls by months may be examined. Such an examination should have an especial significance in showing the relations which meteorites may have to well-known star showers. Two of the best known of these showers occur in August and November. If meteorites are related to these, these months should show a larger fall than others. If meteorites are not related to these, no special increase for these months should be shown. On compiling the results the latter proves to be true. The months exhibiting the greatest number of falls are May and June. The number for November falls below the average and that for August rises only slightly above. The evidence from this record is therefore that meteorites are not related to the best known star showers. It is fair to presume that the record by months will be somewhat influenced by the time that observers are most abroad. Most of the observations of meteorite falls are made in the northern hemisphere and in this hemisphere observers are more likely to be out of doors and hence more likely to observe the fall of meteorites in the summer than in the winter months. The record shows that as a whole the number of falls recorded *is* less for the winter than the summer months, yet the number of falls cannot be influenced by that alone since the high record for May and June drops to nearly half that number in July. Further the months of August, September and October are

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* Pop. Sci. Mon. 1904, pp. 351–354.

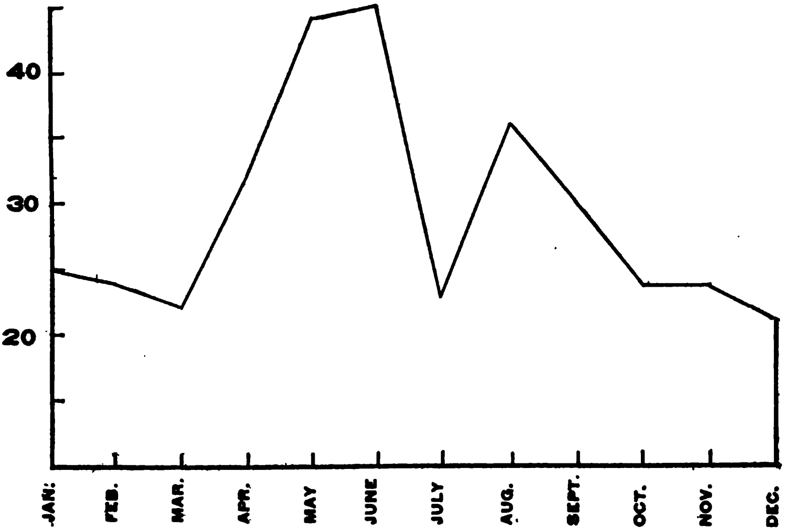

FIG. 1. Falls of meteorites by months.

equally favorable as regards weather for observations of meteorite falls with those of April, May and June, yet the latter period much excels the former in number of falls. The excess of falls in May and June must, therefore, be due to other causes than favorable conditions of observation and seems to indicate that in the portion of the earth's orbit passed through in these months there is an unusual number of meteorites. The full record for the different months is as follows:

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
25	24	22	32	44	45	23	36	30	24	24	21 = 350

This record is shown graphically in the accompanying diagram, fig. 1.

Comparison of the falls of meteorites by months as here given with those of falling stars and fireballs as given by W. H. Pickering* shows a marked difference of distribution. According to Pickering's list the falling stars and fireballs are much more uniformly distributed through the year than are meteorites, and the period of greatest number is from July to November. In May and June their number is at its minimum. Hence the record seems to show a difference in character between meteors and meteorites and furnishes *per se* a ground for questioning the gradation that has been supposed to exist between meteors and meteorites.

* Popular Astronomy, No. 165.

Tabulation of meteorite falls by days of the year seems to show little of significance. The largest number of falls for any one day is five on October 13, and this is a month when the total number of falls is not large. Four days of the year show four falls each and 158, or nearly half the total number, no falls at all. The days without falls seem to be scattered indiscriminately through the year, without marked grouping or arrangement. The days showing falls aside from those mentioned have from one to three falls each without any marked grouping that is apparent. Such a record seems also to indicate that to refer a meteorite falling on the day of a star shower to such a shower is unsafe, especially if the observations are not sufficient to assign the two to the same radiant. Meteorite falls are so distributed throughout the year that the two occurrences might easily be coincident without being otherwise related.

Of all times of fall of meteorites the most satisfactory for study are probably the hours of fall, since the ratio of number of falls to number of hours is larger than to days, months or years. As is well known, the hours of fall show the direction of movement of meteorites, since (with a few minor possible obvious exceptions) meteorites falling from noon to midnight, or afternoon falls, must be moving in the same direction as the earth; while those falling between midnight and noon are moving in a direction opposite to that of the earth or else at a speed so slow that they are overtaken by it. While the hour of fall is not known of as many meteorites as is the year and month, yet of 268 sufficiently satisfactory records are available. Of these 268 falls 180 occurred in the time from noon to midnight, and 88 from midnight to noon. Meteorites, therefore, in the proportion of at least two to one, have direct motion and overtake the earth. Of the others it is probable that the majority have retrograde motion, since observations indicate that but few, comparatively, are traveling at so slow a speed as to be overtaken by the earth. As in the case of the months and the years, it is quite likely that here also considerable allowance should be made for conditions of observation. It is reasonable to expect that the number of falls recorded in the early morning hours would be less than that for other times, since mankind is generally asleep then. That some such allowance must be made is indicated by the records, for the number of falls from midnight to 6 A.M. is only 21, while from 6 A.M. to noon it is 67; from noon to 6 P.M. 122, and from 6 P.M. to midnight 58. Hence it seems probable that some of the diminution in the number of falls is due to lack of observers, although Newton* concluded from studies of the orbits of the morning falls that the lack of observers had little to do with their scarcity.

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*This Journal (3), xxxvi, p. 10, 1888.

During the other periods of the day, however, the figures should be little affected by conditions of observation and there seems much reason for reaching the conclusion that the majority of meteorites have direct motion and travel at a velocity greater than that of the earth, or 18 miles per second. Here again meteorites differ from meteors, since the larger number of meteors fall in the morning hours. In times of fall by months, days and hours, therefore, the majority of meteorites differ from meteors. Their position in space, orbits and direction of movement must, therefore, differ correspondingly also.

Field Museum of Natural History,
December 15, 1909.

Art. XVI.—*Note on the Occurrence of Astrophyllite in the Granite at Quincy, Mass.*; by L. V. Pirsson.

The interesting note of Professor Warren on the finding of a pegmatitic facies of the alkalic granite of Quincy,* and of the minerals it contains, recalls to the writer that he has recently noticed in a specimen of this rock the mineral astrophyllite. The occurrence is entirely a microscopic one and the crystals are too minute to be detected and tested megascopically, but as the real home of this rare and peculiar species, as shown in the few places in which it has so far been found—Langesund fiord, South Norway; southern Greenland, and St. Peter's Dome, Colorado—is in the pegmatites of the alkalic rocks, it seems worth while to call attention to the occurrence in order that it may be placed on record, and that attention may be directed to the Quincy pegmatites in the hope of finding it in megascopic crystals. This is more especially necessary since from its dark or brownish color and excellent micaceous cleavage it is apt to be mistaken for biotite and overlooked. A chemical test for titanium will, however, serve to distinguish it readily from ordinary biotite and zinnwaldite, while lepidomelane, which might be expected in such associations of minerals, rarely contains more than a trace of this element. In this connection it might be stated that the writer has not observed any of the dark micas in the study of a considerable number of sections of the Quincy rock, although White† mentions it as occurring at times in minute flakes.

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* This Journal, vol. xxviii, p. 449, Nov. 1909.

† T. G. White, Petrography of the Boston Basin, Proc. Bost. Soc. Nat. Hist., vol. xxviii, No. 6, p. 131, 1897.

The astrophyllite was found in a rock of the usual Quincy type consisting of riebeckite, aegirite, microperthite and quartz, with zircon as the most common accessory mineral. It is in minute, elongated laths grouped into bunches and associated with the riebeckite. It was also observed intergrown with the riebeckite in such a way that the axis of elongation parallel to the cleavage was parallel with the vertical axis of the riebeckite; hence in section it appears as if wedged in between the hornblende cleavages. It was noticed that the riebeckite in this case had on its margin with the feldspar what the writer has drawn and figured as the interdented texture,* indicative of crystallization from eutectic conditions.

The astrophyllite was found to have the following properties: cleavage, excellent micaceous, and accepting this cleavage as the pinacoid *b* (010) the direction of elongation of the crystals is on the *c* axis and the directions of elasticity are $a = \mathfrak{c}$; $b = \mathfrak{a}$ and $c = \mathfrak{b}$; strongly pleochroic, $\mathfrak{a}$, red-orange, $\mathfrak{c}$, lemon-yellow; absorption $\mathfrak{a} > \mathfrak{c}$; refractive index >1·7; extinction parallel to the cleavage cracks; birefringence high >0·04. In convergent light a single biaxial optic axis was obtained on the edge of the field; the limited number of crystals and their nearly parallel orientation did not permit of further investigation of the optic scheme.

These are the properties of astrophyllite and definitely determine it; from the micas, which it resembles in thin section, it is easily distinguished by the much higher relief, the reversal of the absorption scheme referred to the cleavage and the wide optic angle indicated.

There is yet much to be learned concerning this interesting mineral, whose formula is still uncertain, but which Brögger† believes to be $\overset{\mathrm{I}}{R}_4\overset{\mathrm{II}}{R}_4Ti(SiO_4)_4$ in which $\overset{\mathrm{I}}{R} = H, Na, K$ and $\overset{\mathrm{II}}{R} = Fe, Mn$, and a new occurrence well investigated might be expected to throw much light upon its composition.

Sheffield Scientific School of Yale University,
New Haven, Conn., Nov. 1909.

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* Contributions to the Geology of New Hampshire. No. III, On Red Hill, Moultonboro; this Journal, vol. xxiii, p. 273, 1907.

† Zeitschr. für Kryst., xvi, p. 212, 1890.

Art. XVII.—*The Crystallization of a Basaltic Magma from the Standpoint of Physical Chemistry*; by Clarence N. Fenner.

Introduction.
Scope of the article.
Part I.
Process of crystallization as demanded by the laws governing eutectiferous solutions.
Petrographic description of the Watchung basalt.
Part II.
The crystallization of a magma as affected by the law of mass-action.
Displacements of equilibrium within a solution effected by changes of temperature and pressure — van't Hoff's law.
Resorption of olivine in the Watchung magma.

Introduction.

Within the last few years petrographers have recognized the important aid which might be rendered to the interpretation of the structure and history of igneous and metamorphic rocks by an application of the principles of physical chemistry. The discoveries which have been made regarding the laws governing the crystallization of solutions, the application of the phase-rule of Gibbs and of the law of mass-action, and the new conception of the phenomena of solid solutions, are believed to be capable of rendering very great assistance in interpreting the meaning of the structures with which petrographers have become familiar.

Although the applicability of these principles is generally conceded, very little has yet been done in applying them to specific cases.

In making a study of certain peculiar phases of the basalt which forms the Watchung Mountains in New Jersey, it came to be recognized that the rather unusual conditions which had attended its solidification had produced results which illustrated certain laws of the crystallization of solutions more perfectly than could be hoped for from the most elaborately devised laboratory experiments.

In a previous article* the author has shown that the Watchung sheets were surface flows poured out over areas in which Triassic shales and sandstones were accumulating under conditions of continental sedimentation in structural valleys.† At most points the basalts present the dense, holocrystalline texture normal to this type of rock, but in certain areas the flows appear to have spread over the sites of shallow lakes, and many modifications of structure resulted. The chief effect, as regards the features which will be considered in this paper, was that the fused magma was rapidly chilled and rendered viscous. In places the stiffening liquid accumulated in masses of rounded or bowlder-like forms similar to the "pahoehoe" of Hawaiian flows. The progress of crystallization was checked at various stages and the bowlder-forms were crusted with basaltic glass, in which examination with the microscope shows few phenocrysts, while the more slowly cooling interiors of the bowlders assumed the normal texture. Between the two types transitions occur, by which one may trace the passage of the microlites of the vitrophyrs into the well-developed crystals of normal basalt.

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* Features Indicative of Physiographic Conditions Prevailing at the Time of the Trap Extrusions in New Jersey. Journ. of Geol., vol. xv, No. 4, May-June, 1908.

† See also J. V. Lewis, Annual Report N. J. State Geol. Survey for 1906.

The glass-encrusted bowlders are especially well developed in an area lying between Paterson and Montclair Heights. Quarries have been opened at several points, as it has been found that this variety of trap is easily blasted and crushed for road-material. It has therefore been possible to obtain material for petrographic study unacted upon by weathering.

SCOPE OF THE ARTICLE.

Two principal features of the Watchung basalt will be considered, and in accordance with this the article is divided into two parts. Part I will deal with the order of crystallization of the constituent minerals, and it will be shown that, contrary to certain prevalent ideas regarding the order of succession of the minerals of a basaltic rock, the three constituents, plagioclase, diopside, and magnetite, began to appear almost simultaneously from the magma and continued to crystallize side by side until complete solidification was attained. In order to show that this result is demanded by the laws of crystallizing solutions, a very brief outline of these laws will be given as a preliminary to the petrographic study.

In Part II resorption-phenomena will be considered in connection with the resorption of olivine, a minor feature as regards the constitution of the rock, but very significant in its interpretation.

The law of mass-action will be considered in this connection, and the author will endeavor to show that the usual explanation of resorption is inadequate to explain certain phases of the phenomenon, but that a very satisfactory explanation may be derived from an application of van't Hoff's law.

PART I.

Process of Crystallization as demanded by the Laws governing Eutectiferous Solutions.

In order that the crystallization of a magma may proceed strictly along the lines indicated by eutectic laws, it is essential that there shall be little or no reaction going on within the magmatic solution from the time that the initial crystals appear until the process of solidification is complete. In such cases the progress of solidification is very regular. Each compound present in the fusion has its temperature of solidification depressed according to the number of mols (gram-molecules) of other substances present and begins to appear at the appropriate point in the process of cooling. That mineral will first appear which, under the conditions stated regarding fusing-point, still has the highest temperature of fusion.

The first mineral may be regarded as that which is present in greatest excess over the eutectic ratio. Within a certain range of temperature it alone will be thrown out of solution. At a certain point, however, it will be joined by a second mineral, and these two in turn by a third. The composition of the solution approaches the eutectic ratio by the elimination of those constituents which are in excess. A sudden chill at any stage of the process causes a great increase of viscosity, which acts as a very effectual check to further crystallization. The result is the production of the greatly undercooled liquid of immense viscosity which is termed a glass. The composition of the glass depends upon the stage of progress toward the attainment of the eutectic ratio which has been reached. If no such interruption occurs, at the eutectic point the group of minerals forming the eutectic will crystallize out in the proper ratio. No further depression of the temperature of solidification can occur, and the loss of heat will be merely that due to the latent heat of fusion given up by each mineral in passing from the liquid to the crystalline phase. An application of the phase-rule of Gibbs confirms this conclusion, for at the eutectic point the number of phases exceeds the number of components by one, and no change of temperature or composition of the system can occur.

It is doubtful whether the solidification of a magma is ever quite such a simple process as is expressed in the form described, but though complications may ensue, the underlying principles of eutectics hold and should constitute a guide of great value in interpreting rock structures and history. In the solidification of the Watchung magma the reactions which would tend to obscure the process were of such nature that their results do not offer great obstacles. The only one of moment is that by which olivine was crystallized out and later was resorbed by the magma and did not again appear. This phenomenon will require explanation, but it is due to other physico-chemical laws, and the reaction was so nearly complete before the three final constituents, diopside, plagioclase, and magnetite, began to appear, that its effects may be disregarded for the present.

Petrographic Description of the Watchung Basalt.

In those portions of the Watchung flow in which chilling was most rapid the surfaces of the pahoehoe-like bosses were crusted with much glassy material. Apparently, however, judging from the study of a great number of slides, crystallization was under way and phenocrysts had begun to appear in the mass of flowing lava before the sudden chill occurred which stiffened it into a glass. The resultant glass shows a typical vitrophyric texture. The well-developed phenocrysts are surrounded by isotropic glass or by a groundmass in which glassy material is more or less mixed with the feathery forms of microlites. Under the generally accepted hypothesis, in a typical diabase consisting of magnetite, plagioclase, and diopside, the magnetite would be first to form, and its elimination from the magma would be complete before the plagioclase began to appear. These two are held to be followed by the third constituent, diopside, which occupies the space left by the other two. On the other hand, the manner in which the minerals should crystallize out, as demanded by the principles of eutectiferous solutions, is quite different, and in every case the sections examined conform to the latter requirements. No matter to what degree glass may be present in the slide, plagioclase and diopside appear side by side. It is evident that almost from the beginning of crystallization these two constituents were being eliminated simultaneously. At times it appears that the diopside is in somewhat preponderant amount, and at other times the plagioclase.

With regard to the magnetite the evidence is more obscure. The proportion of magnetite in the magma is not large and it seems to appear first as a dark dust. The exact point at which elimination from the fusion began is not clear, but it is certain that growth of magnetite grains continued while diopside and plagioclase were still forming.

Slide No. 105 shows a typical development of glass and phenocrysts. (See fig. 1.)

Probably three-fourths of the section is isotropic glass, uniformly pale green or light olive-green in the thin section. Scattered throughout are numerous phenocrysts of plagioclase and diopside. The plagioclase is in typical lath-like crystals reaching an ordinary maximum of $0{\cdot}2-0{\cdot}3^{mm}$ long by $\cdot05^{mm}$ wide. The diopside is developed in more nearly equidimensional forms of a characteristically stouter appearance. An exceptionally large crystal measured $0{\cdot}6$ by $0{\cdot}2^{mm}$. The outline is sometimes octagonal, but in general irregular. In many cases the plagioclase and diopside are closely associated, small clusters of mutually intergrown individuals lying in groups surrounded by glass. It is noticeable in such cases that while the plagioclase laths are indented by the diopside crystals, the characteristic elongated form of the plagioclase is maintained.

These phenocrysts of diopside and plagioclase are bordered by dark plumose growths, or hair-like tufts, fading out at the periphery into the surrounding glass. Under the high-power objective they are resolved into innumerable microcrystalline growths, straight or curved, sometimes branching in lattice-like forms, thrown out from the boundaries of the phenocrysts. With the high magnification they exhibit the development sketched in fig. 2.

Fig. 1.

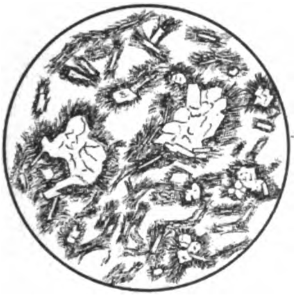

Fig. 1. Typical structure of the vitrophyric phase resulting from quick chill. (Slide No. 105.) Elongated crystals plagioclase, stouter forms diopside, matrix light-green glass, perfectly isotropic. Actual diameter of field 1·5^{mm}.

Fig. 2.

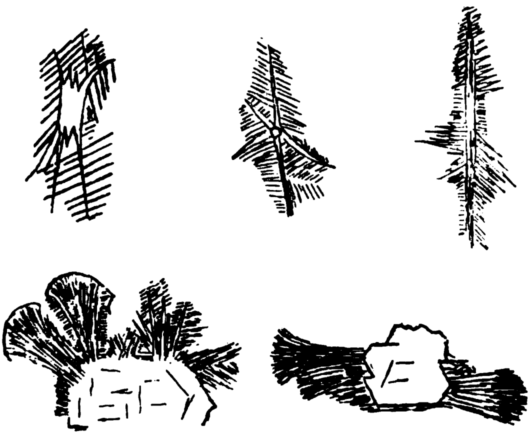

Fig. 2. Microlitic growth of plagioclase and diopside, greatly magnified.

The phenocrysts were probably formed during rather slow cooling in the flowing mass of lava, and the bordering microlitic growths represent the continuation of the crystallization during the initial stages of chilling, before increasing viscosity put a stop to the process. Their brown color seems best explained by the separation of magnetite dust at the same time that diopside and plagioclase were crystallized out. If this is true, the eutectic ratio had been reached, and if normal crystallization had been followed the continuation of the process would have taken the form of simultaneous growth of crystals of diopside, plagioclase, and magnetite. This was prevented by the increasing viscosity of the liquid, with which crystallization could not keep pace.

The almost simultaneous appearance of diopside and plagioclase at the initiation of crystallization, attended or followed after only a short interval by magnetite, would appear to demonstrate that the composition of the magma as erupted did not differ greatly from that required to form a eutectic of the three.

The only other feature of interest in the slide is the presence of a number of olivine crystals, which have been strongly attacked and resorbed by the magma. This phenomenon will be taken up later.

Slide No. 1 is almost a duplicate of No. 105 and exhibits the same set of phenomena, except that there is no evidence of olivine grains, and that the glassy groundmass shows with high magnification abundant brown dust. Diopside phenocrysts are a very minor constituent but plagioclase is abundant.

In No. 57 the chilling was apparently a little less sudden, for the phenocrysts have a tendency to blend with the plumose microlitic borders and a smaller proportion of the slide is occupied by strictly undifferentiated glass.

Slides 30, 85, and 90 are other examples showing essentially the same relations of phenocrysts, microlites, and undifferentiated glass. In No. 132 (fig. 3), the microlites are seen to be spreading over a greater portion of the field, and in No. 2 a further stage is shown.

This latter slide was taken from the same hand specimen as No. 1, but whereas the portion of the rock from which No. 1 was taken presented a decidedly vitreous appearance, that from which No. 2 was prepared was a little farther removed from the chilled crust and was of a felsitic character. Microscopic examination confirms the deduction which would naturally be drawn. In No. 1 the phenocrysts are merely bordered by plumose microlites and a large part of the section is undifferentiated glass. In No. 2 the microlites have spread over the entire field not occupied by the phenocrysts and no glass can be perceived. Instead there is a beautiful development of tufts and sheaves of feathery microlites occupying the entire groundmass. The phenocrysts, as before, show groups of diopside and plagioclase in mutual intergrowth. The general dark brown color of the groundmass appears to be due to dust and grains of magnetite developed along the lines of growth of the feathery microlites and outlining their form.

FIG. 3.

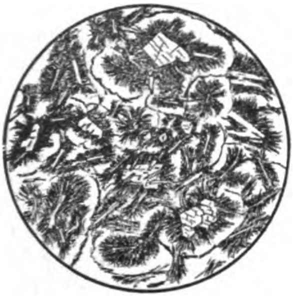

FIG. 4.

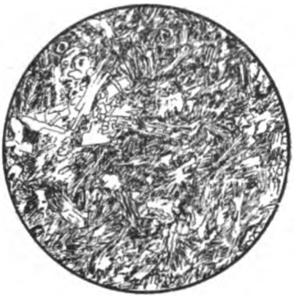

FIG. 3. Microlitic additions to phenocrysts of diopside and plagioclase. (Slide No. 132.) Diameter of field 1·5^{mm}.

FIG. 4. Intermediate texture between microlitic and holocrystalline. (Slide No. 58.) Diameter of field 1·5^{mm}.

In slides No. 96 and No. 58 (fig. 4) a step in advance is shown toward the holocrystalline texture of a normal basalt resulting from moderately slow cooling. The sharply defined outline of the phenocrysts has been lost and their borders fray out into the finely crystalline groundmass. The groundmass itself is coarser than in the earlier described sections and the subhedral crystals are comparable in size to the phenocrysts. Some of the magnetite is in distinct grains, but much of it is still in the form of a dark dust lying between the lighter minerals.

Nos. 98, 99, and 18 (Photograph, fig. 5) show successively coarser phases of crystallization, and Nos. 23, 24, and 25 show the normally developed texture of these basalts. Nos. 47 and 64 represent the maximum of coarseness of crystallization attained.

In the normally crystallized basalt the essential constituents are plagioclase, pyroxene (diopside), and magnetite, the first two in crystalline forms, the last in dust, granules, or trellis-like groups. (See fig. 6.)

The plagioclase is in lath-shaped crystals, euhedral to subhedral, generally showing two or three stripes of albite-twinning lamellæ. Pericline twinning is rarely present. Its average dimensions are ·15 by ·03^{mm}, but occasionally crystals of larger size up to 1^{mm} in length, and more nearly equidimensional, are scattered through the mass. It comprises, roughly speaking, two-fifths of the whole.

Fig. 5.

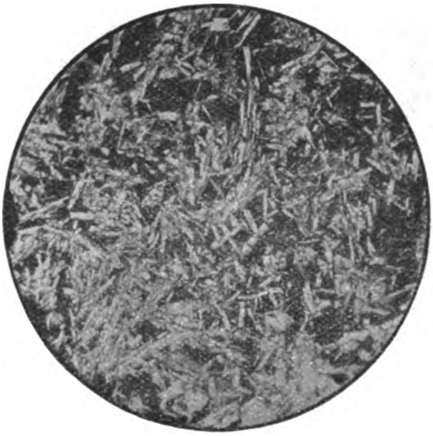

Fig. 5. Photograph of normally crystallized basalt. (Slide No. 18.) Diameter of field 2¼^{mm}.

Fig. 6.

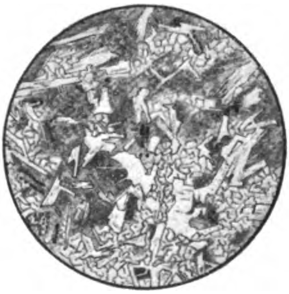

Fig. 6. Ophitic texture of normally crystallized basalt. (Slide No. 47.) Plagioclase laths, diopside granules, and crystals and dust of magnetite in mutual intergrowth. The magnetite is mostly included in the diopside, but partly also in the plagioclase. Diameter of field 1·5^{mm}.

Extinction angles measured on symmetrically extinguishing albite twins give maxima of 33–34 degrees. This indicates a medium labradorite of about the composition Ab 40 An 60.

The pyroxene is in stouter forms of an irregularly angular outline. The grains show a tendency to coalesce in groups of individuals of different extinction. Single units show dimensions of 0·2 by 0·15^{mm} with occasional larger grains up to 0·5^{mm} in size. The crystals are almost colorless, with a faint tinge of brown or green. In many slides twinning is a common characteristic. Twinning and composition plane the orthopinacoid (100). Polysynthetic basal twinning is absent. Optical character biaxial and positive. No difference in dispersion between red and violet can be perceived. Prismatic cleavage often poor in the small grains but well developed in the larger. Birefringence 0·020–0·022.

Extinction measured from the ortho-pinacoidal twinning plane to the axis of minimum elasticity, *Z*, gave angles of 45 degrees. The mineral is evidently not pure diopside, but whether it varies toward hedenbergite or toward augite would be difficult to determine without chemical analysis. It is referred to as diopside. The quantity is somewhat in excess of the plagioclase.

The magnetite is seldom in euhedral crystals, more often in fine dust or in trellis-like or fir-tree groups. During the crystallization of the plagioclase and diopside the magnetite appears to have been mechanically pushed aside until the last stages of crystallization were reached, and then included within the final crystals of the lighter constituents, to which it gives a dark brown color. Even in the final stages the plagioclases seem to have had the power to free themselves of the magnetite dust fairly effectually, and most of it is included within diopside grains. A small portion is enclosed within irregular patches of light-green chloritic material, which may represent resorbed olivines subsequently chloritized.

In addition to these essential constituents there are a number of well-defined areas of what was originally olivine, but which show strong resorption and later alteration to serpentine and chlorite.

The magnetite in these rocks is probably titaniferous, as it gives rise on decomposition to milky-white leucoxene.

In examining those slides which have the texture normal to basalts the plagioclases appear to have the crystals developed in more nearly euhedral forms than the diopside, and it might be argued that this is confirmatory of the generally accepted view that the growth of the plagioclases was finished before that of the diopside began, and that the latter mineral molded itself around the plagioclase. It is only necessary, however, to devote a little study to the question to determine that this is emphatically not the case. In those vitrophyric rocks first described (e. g. No. 105 and No. 57) in which plagioclase and diopside undoubtedly developed while swimming freely in a liquid, the plagioclase is bounded by plane faces, while the diopside has irregular outlines, and it appears that this difference in development is due to the mode of growth, the cause of which is not germane to the subject. When, in the more glassy types, the plagioclase and diopside form groups of intergrown crystals, as they often do, the characteristic form is shown in fig. 7, a notable feature of which is the manner in which the plagioclase laths wedge out toward the central portion of the diopside grains.

Fig. 7.

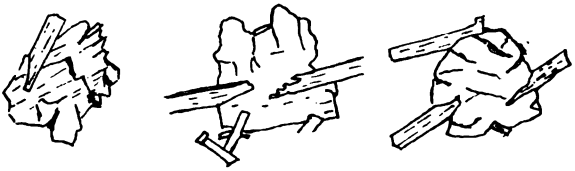

Fig. 7. Intergrowth of diopside and plagioclase. (Slides Nos. 2 and 57.)

These features are apparent in all phases of development of the basalt from glassy to holocrystalline, and alone would be

Fig. 8.

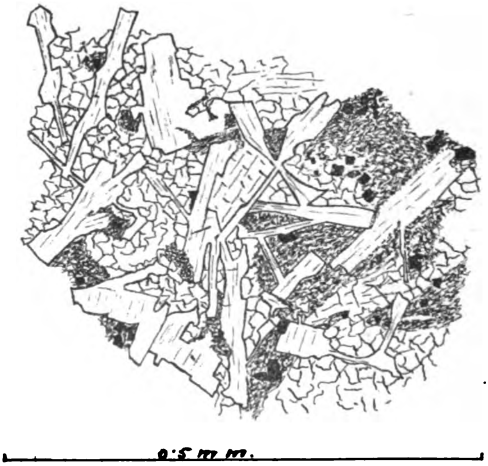

Fig. 8. Modification of forms of plagioclase and diopside resulting from simultaneous crystallization. A few magnetite grains (black) and some chlorite (gray) are also present (Slide No. 64).

almost conclusive evidence of simultaneous growth of the two minerals.

In the holocrystalline phases the plagioclase gives, at first, an impression of being much more euhedral than the diopside, but it is almost impossible to find a crystal in which the symmetry is not destroyed by encroachment of diopside, and the extremely irregular growth of plagioclase sketched in fig. 6 (Slide No. 47) and fig. 8 (Slide No. 64) is entirely normal and characteristic.

FIG. 9.

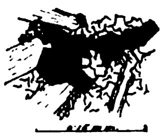

FIG. 9. Intergrowth of magnetite, diopside, and plagioclase (eutectic structure—Slide No. 23).

The magnetite is often in such fine grains that no conclusions can be drawn regarding its period of growth, but in No. 23 it is found in better developed crystals, which show unmistakably a simultaneous deposition with plagioclase and diopside. Fig. 9 shows the general relations.

PART II.

The Crystallization of a Magma as affected by the Law of Mass-Action.

It was pointed out on a preceding page that in order that the crystallization of a magma should follow strictly the laws of eutectiferous solutions the compounds present in the fusion-solution should have no inter-reaction during crystallization, but that simply the freezing-point of each should be depressed by the presence of the others and each should begin to crystallize at the appropriate temperature as thus modified. In the Watchung magma it appears that this ideal course was nearly realized as regards the final products of crystallization, and in many other cases this is probably true, especially where the range of temperature from the beginning of crystallization until the final consolidation of the eutectic is not large and where great variations of pressure do not occur. Reference was made, however, to resorbed olivines which appear in certain slides, and resorption-phenomena are of common occurrence in the study of igneous rocks. Their chief features are explainable by the law of mass-action.

It is well understood that when substances capable of reaction are brought together in a solution the reaction does not ordinarily proceed to completion, but that in principle every reaction is reversible and the degree to which a reaction will proceed under given conditions of temperature and pressure is dependent primarily upon the concentrations or active masses of the substances participating.

In solutions of molten silicates it is recognized that we have very little knowledge of the extent to which reactions proceed to attain equilibrium; but we know that the state of equilibrium, i. e., the proportions in which various mineral compounds exist in the solution, depends upon the concentrations of the various oxides present.

If we imagine that in a solution of this nature in which equilibrium has been attained, crystallization begins, it is seen that a disturbing factor is introduced; for the removal by crystallization of one or more compounds is constantly changing the relative proportions of the substances left in the mother-liquor. It is evident that certain substances which may have been present in small amount in the original magma may reach a high degree of concentration in the residual dregs of mother-liquor. The conditions of equilibrium are completely shifted. New compounds are formed, while those compounds which were present in preponderant amount in the original magmatic solution may be entirely broken up and destroyed. As a result the crystals first deposited become unstable in contact with the mother-liquor and are either taken up by the solution or react with it to form zones of new minerals. This consequence of the principle of mass-action is well understood. Pirsson has thus explained reaction-rims of enstatite and biotite surrounding olivine crystals and separating them from alkali feldspar in the shonkinite of the Little Belt Mountains, Montana.*

While it is possible to account for certain phases of the phenomena of resorption in this manner, there are others which cannot be brought into line with this explanation. Magmas consolidating at depth frequently exhibit a different association of minerals from magmas of the same composition consolidating on the surface; and a magma in which intra-telluric crystallization has begun may, when erupted at the surface, attack the minerals first deposited and take them more or less completely into solution, and in the final consolidation these minerals may not re-appear. In the Watchung magma olivine crystals of the intra-telluric period were attacked and in most cases almost completely resorbed before any notable development of the three final products of surface crystallization appeared. In this case it is obvious that the phenomenon cannot be explained by reference to a concentration of material in a residual mother-liquor. To account for such occurrences the author would offer another explanation, based upon the displacements of equilibrium which take place within a solution under conditions of simultaneous diminution of pressure and temperature.

Displacements of equilibrium within a solution effected by changes of temperature and pressure—van't Hoff's law.—The extension of the law of mass-action to include changes of temperature was developed by van't Hoff. The principle is of great importance, but it does not appear to have received the attention it merits in the study of petrological problems.

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* L. V. Pirsson: 20th Ann. Rept. U. S. Geol. Sur., 1898–99, p. 482.

The basic principle of van't Hoff's law is that change of temperature displaces the equilibrium within a solution. If, then, crystallization of a magma can be brought about, in one case at a higher and in another case at a lower temperature, the chemical state of the solution as regards compounds existing within it will be different in the two cases. Change of pressure between the depths of the earth and the surface is an effective agent in changing the temperature at which crystallization begins. Pressure alone, as has been pointed out by several writers,* is not capable of causing great variations in the melting-points of minerals; but it is quite conceivable, and in fact probable, that within a complex solution the variation of the temperature of crystallization caused by relief of pressure is often attended by displacements of equilibrium, such that reactions proceed further in one direction or another and the relative proportions of the various compounds present is altered. These displacements of equilibrium find corresponding expression in the point at which crystallization is initiated and in the minerals deposited. The change thus begun tends to progress continuously in the same direction and may result at the final consolidation in an association of crystallized products quite different from what would be found under conditions of greater pressure.†

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* A. Harker: The Natural History of Igneous Rocks, New York, 1909, pp. 163 and 194.

† The effects of temperature and pressure upon reactions within a system of the nature of a magmatic solution are expressed by two fundamental equations. The first is van't Hoff's formula

$$\log K' - \log K = \frac{q}{R}\left(\frac{1}{T'} - \frac{1}{T}\right)$$

in which K′ and K are the constants of mass-action at the (absolute) temperatures T′ and T, q is the heat of the reaction per unit considered, and R is the gas-constant (= 2 cal.)

From this equation it follows that with decrease of temperature (T greater than T′) a reaction which evolves heat (q positive) is driven forward or in that direction in which heat is given out. (It will be noted that this is in accord with Le Chatelier's theorem.)

If, for example, two substances, A and B, unite to form AB with evolution of heat, the formation of the compound AB will increase as the temperature is lowered, and the greater the value of q the greater will be the amount of the compound formed.

The effect of pressure in inducing crystallization at a higher temperature is expressed by the formula

$$\frac{\Delta p}{\Delta T} = \frac{w}{T(v_1 - v_2)}$$

in which Δp is the pressure required to cause crystallization to begin at the temperature increased ΔT degrees above the normal crystallizing point, w is the latent heat of fusion, T is the absolute temperature, and v_1 and v_2 are the specific volumes of the substance in the liquid and solid forms respectively.

Resorption of Olivine in the Watchung Basalt.

In hand specimens, both of the vitreous and the aphanitic varieties of the Watchung basalt, small, dark-green spherulitic bodies can often be seen. They appear in many of the thin sections and are found to be built up of concentric shells of lighter and darker material of chloritic or serpentinous nature. A typical example is shown in slide No. 105 (fig. 10).

FIG. 10.

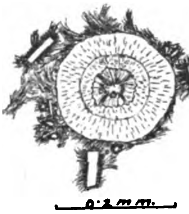


FIG. 10. Chloritic nodule in vitrophyr (Slide No. 105).

The diameter of the spherulite is about $0{\cdot}2^{mm}$, but larger ones are not uncommon. The central portion is composed of comparatively large blades of radial chlorite, decidedly birefringent. The outer shells are very feebly polarizing and appear to be made up of minute scales of chlorite mingled with isotropic glass. Beyond the border of the spherulite the normal vitrophyric structure is found, consisting of small crystals and grains of feldspar and diopside and brown microlitic tufts, set in the paste of glass. In this case resorption and alteration have progressed so far that there is almost nothing suggestive of the manner in which the spherulite originated, but in other cases the evidence is plain. Outlines of some original mineral are left, to whose resorption by the magma the spherulites are attributable. None of the mineral itself remains,

FIG. 11.

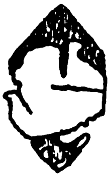


FIG. 12.

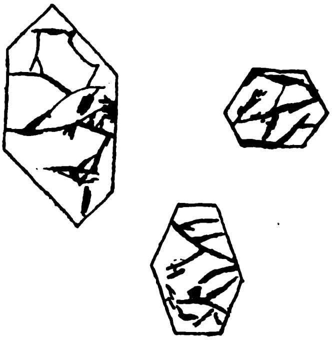


FIG. 11. Partially resorbed olivine, subsequently altered. (Slide No. 105.)

FIG. 12. Separation of oxide of iron along cracks in olivine crystals which have been replaced by secondary products.

the crystal outlines being filled with chlorite, calcite and other alteration products. These retain certain features, however, which point strongly to olivine.

All stages of resorption appear in different parts of this slide. An example is sketched in fig. 11. Without the analyzer the corroded forms shown in heavy lines in the sketch (now replaced by calcite) are all that appear, but with crossed nicols the crystal form, almost complete, is brought out in serpentine. Immediately adjacent are remnants of several other crystals which the crossed nicols similarly outline.

In fig. 12 the typical manner in which oxide of iron has separated along cleavage cracks of the original mineral is shown, although nothing but alteration products survive. The resemblance to olivine is obvious.

From such examples one may pass by gradual transition to the results of almost complete resorption, in which the rounded and blurred outlines convey only a vague suggestion of the original form of the crystal, and upon whose areas, spreading out into the glass, microlites are encroaching. The color in such cases is practically the same as that of the surrounding glass, but crossed nicols show the presence of aggregates of minute chlorite scales.

The stages of the process and the relations which the olivines bear to the plagioclase and diopside are sketched in fig. 13. Similar phenomena are shown in slide No. 83, in No. 30, and in No. 48. In No. 57 the several steps can be followed very perfectly.

FIG. 13.

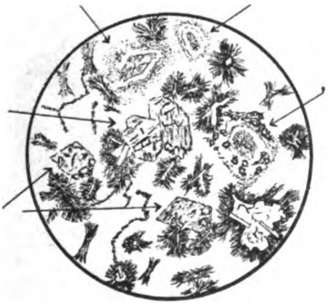


FIG. 13. Breaking-up and resorption of olivine. Several stages, found in various portions of the slide, are brought together. (Slide No. 105.) Diameter of field 1·5^{mm}.

In No. 54 the outline of an original olivine crystal is preserved, but most of the area within the boundary of the original crystal is occupied by a mixture of brown glass and irregular grains of a dark brown color. This form of attack upon the olivine, by which the crystal has been broken up into many fragments, appears to have been common, and the brown grains show up in many of the slides, at times associated with chloritic areas retaining a suggestion of a crystal unit, and again scattered through the glass.

FIG. 14.

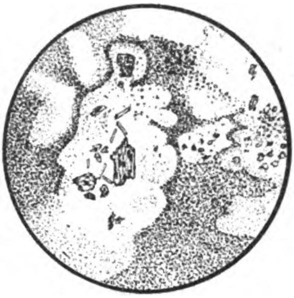


FIG. 14. Inclusions in glass, resulting from the breaking-up of olivine crystals. (Slide No. 17.) Diameter of field 1·5^{mm}.

These effects are shown in slide No. 17, sketched in fig. 14. The greenish glass is filled in places with brownish inclusions, arranged in crescentric or cusp-like figures. The inclusions appear to be in part surviving fragments of olivine, and in part magnetite dust set free in the reaction. The figures

FIG. 15.

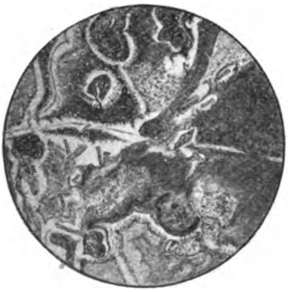


FIG. 15. Effects of resorption of olivine accentuated by secondary alteration. (Slide No. 54.) Diameter of field 1·5^{mm}.

assumed would appear to be due to the manner in which the resorbed material was diffusing in the surrounding magma when increasing viscosity terminated the process. Diopside and plagioclase are present in minor amount.

A slight degree of subsequent zeolitic alteration of glasses containing partially resorbed olivines serves to accentuate the features described. This is seen in slide No. 54 (fig. 15) and in many other cases. Even in advanced stages of secondary alteration traces of these features persist.

In all cases the olivine shows unmistakably that corrosion had attacked it and that it was in process of resorption by the magma, from which plagioclase, diopside, and magnetite were beginning to crystallize. At some point in the history of the magma the olivine which was first deposited became unstable and would undoubtedly have gone completely into solution if sufficient time had been allowed. It is noticeable that in the later crystallization olivine did not again appear as one of the products. It must follow, therefore, that the olivine molecule which was absorbed underwent some change within the solution by which it entered into new combinations.

Considered from the standpoint of the principles previously developed, the most probable explanation of the resorption of the olivine appears to be the following: Before extrusion the magma had cooled sufficiently so that crystallization had begun. Inasmuch as most rock-forming minerals occupy less volume in the solid than in the fused condition, the great pressure to which the magma was subjected aided crystallization, so that it was initiated at a somewhat higher temperature than would be the case under less load. The effect upon the crystallization of a given mineral would vary inversely as the heat of solution and directly as the difference in volume between the two states. Pressure may also have had an appreciable effect upon the direction of reaction within the fusion-solution.

Olivine was the chief mineral deposited under these conditions but there are indications that a little plagioclase had also begun to crystallize out. (In slide No. 47 a large plagioclase crystal shows some indication of zonal structure, most probably developed during this period.)

When extrusion of the magma occurred it was attended by great changes in all the physical conditions.

Diminution of load would be a factor of prime importance in causing the minerals which had crystallized out to be resorbed. The loss by volatilization of aqueous and other vapors also affected the combinations existing within the solution. It can hardly be supposed that the vapors evolved existed in the solution entirely in the combinations in which they were given off. Undoubtedly a portion of the vaporized material was combined with the nonvolatile portion and its removal from the system necessitated more or less readjustments of equilibrium throughout.

Under these circumstances it is not surprising that most of the olivine which had been deposited was taken up by the magma. Still if the olivine molecule continued its existence in the re-fused mixture it would be redeposited when the appropriate temperature was reached under the new conditions, but it appears that the lower temperature to which the initiation of crystallization was carried, together with the other disturbing factors, resulted in an entirely new chemical arrangement. The olivine molecules which were resorbed thereby lost their entity, being distributed among other compounds in a manner which cannot be completely followed, and olivine as such did not reappear among the products of crystallization.

The fact that remnants of the olivine persist is due to lack of time given for resorption before increasing viscosity put an end to the process. Under somewhat different conditions, easily conceived, the less complete resorption of a mineral would be attended by the formation of reaction rims, or replacement by an aggregate of other minerals; or its slow solution in a magma in which crystallization was far advanced would constantly change the composition of the mother-liquor, with consequent displacements of equilibria. In the case studied the resorption or solution was nearly complete before the second period of crystallization began, and the effect as regards complexity of results was almost a minimum.

Petrographic Laboratory,
Columbia University.
Nov., 1909.

ART. XVIII.—*Notes on Goethite** (Abstract); by V. GOLDSCHMIDT (Heidelberg) and A. L. PARSONS (Toronto).

IN the summer of 1908 Mr. Parsons collected some specimens of goethite which occurs in veins in carboniferous shale at Walton, N. S. The veins are brecciated and the center filled with calcite. When the calcite was dissolved in hydrochloric acid the goethite was left as a druse of bright crystals.

FIG. 1.

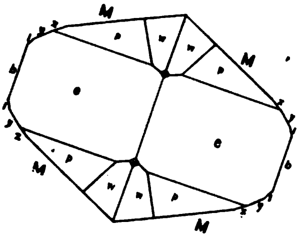
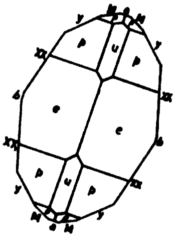
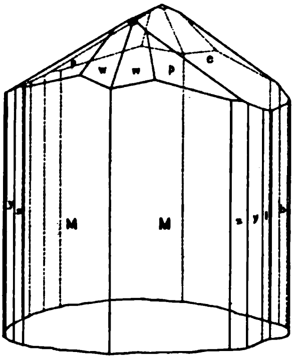
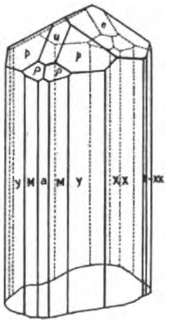


FIG. 2.







Three crystals were measured. The observed forms are: $b = 0\infty\,(010)$; $M = 2\infty\,(210)$; $a = \infty 0\,(100)$; $y = \infty\,(110)$; $XX = \infty 4\,(140)$; $e = 01\,(011)$; $u = 10\,(101)$; $p = 1\,(111)$; $\rho = 31(311)$. The form designated as XX appears in all the crystals as the face with the greatest development. This face is striated lengthwise and is not a single face but a transition face or "Scheinflaeche," and it gives a bright band of light in the prism zone with the angle ϕ varying from 3° to 20°. In this band are bright points which imperfectly indicate the positions of the faces $\infty 3$ (130), $\infty 4$ (140), $\infty 5$ (150), $\infty 6$ (160), ∞ (180), $\infty 12$ (1·12·0). The harmonic discussion of the characteristic indices in this series gives $\infty 3$, $\infty 4$, $\infty 6$, and $\infty 8$ as the points of best position, but no characteristic letter is assigned to them until they have been determined by single distinct reflecting faces. The symbol XX is used for the series and in figure 2, $\infty 4$ represents the series.

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* Abstract of a paper in Groth's Zeitschrift für Krystallographie.

For comparative purposes three crystals from Lostwithiel, Cornwall, were measured and the habit and faces are shown in figure 1. The observed forms are $b = 0\infty$ (010); $M = 2\infty$ (210); $x = \frac{4}{3}\infty$ (430); $y = \infty$ (110); $l = \infty 2$ (120); $u = 10$ (101); $e = 01$ (011); $p = 1$ (111); $w = \frac{4}{3}\frac{1}{3}$ (413). All the forms except x were present on every crystal. The new form $x = \frac{4}{3}\infty$ (430) was present on two crystals and for the best reflections gave angle ϕ 55° 6′ and 55° 33′. A poor reflection gave one face as 57° 27′. Angle ρ was in every case 90°. The calculated angles are ϕ 55° 26′, $\rho = 90°$. The face is small but well defined, and may be regarded as well established. The form $w = \frac{4}{3}\frac{1}{3}$ (413) is also new and is present on all three crystals with four faces on each. The faces reflect well and give a distinct signal cross, but it is worthy of remark that the reflection is slightly yellow while the others are white. The angles agree well among themselves, but in every case the angle ρ is 20′ to 69′ less than the calculated angle. The calculated angles are $\phi = 77° 4′$, ρ 42° 6′. Considering the good character of the reflection and the sharpness of the faces, this difference is not easily understood, but the form may be considered as well established.

Heidelberg, Aug. 14, 1909.

Art. XIX.—*On the Velocities of Certain Reactions between Metals and Dissolved Halogens;* by R. G. Van Name and Graham Edgar.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccvii]

In a reaction between a liquid and a solid, according to the so-called diffusion theory of reaction velocity, a thin layer of liquid adhering to the solid remains unaffected by stirring, and the reaction is maintained by the transport of dissolved substances across this layer by diffusion. When the diffusion is sufficiently slow compared with the other stages of the reaction, the velocity of the whole will be determined by the rate of diffusion alone.

This theory was proposed by A. A. Noyes and W. R. Whitney,[*] in 1897, for the special case of the solution of a solid in a liquid, but Nernst and E. Brunner[†] were the first to suggest its general applicability to the various types of heterogeneous reactions. It was tested by Brunner for cases of simple solution, neutralization, action of acids on metals, and for several electrolytic processes, and has since been accepted by various other investigators as giving the best explanation of the facts in the case of a number of other types of reactions,[‡] including even gas and enzyme reactions.

On the other hand, the validity of the diffusion principle in the case of reactions between metals and acids has been disputed by Ericson-Aurén and Palmaer,[§] and R. Marc[‖] has shown that the crystallization of supersaturated solutions of certain salts seems to follow a different mathematical relation. Recently the theory has been vigorously attacked by M. Wilderman,[¶] who holds that the hypothesis of a diffusion layer is improbable and unnecessary, and shows that the same velocity equation can be derived without it. Furthermore, Wilderman has found that the rate of solution of gypsum is not constant as the theory would require, but varies widely with its physical state, and is different on different surfaces of the same crystal.

The experiments to be described deal with the rate of reaction between dissolved iodine and the metals mercury, copper, silver, cadmium, and zinc, also with those between bromine and mercury, and between cupric bromide and mercury. The work was undertaken with a view to testing the applicability of the diffusion theory, and the results have proved to be in agreement with its requirements in all essential details. A similar field was covered by the work of Schükarew,* in 1891, on the reaction velocities between metals and halogens, but the failure to provide for effective and constant stirring renders Schükarew's results uncertain. So far as known to the present writers, a few experiments by Brunner,† on the rate of solution of pure electrolytic zinc in iodine, constitute the only real test of the validity of the diffusion principle for a reaction between a halogen and a metal, of which an account has been published up to the present time. Brunner does not give his results in detail but found the theory confirmed, especially in the fact the velocity constant agreed with that for the electrolytic reduction of iodine.

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[*] Zeitschr. phys. Chem., xxiii, 689.

[†] Ibid., xlvii, 52 and 56, 1904.

[‡] Senter, ibid., li, 696; Teletew, Dissertation, Heidelberg, 1906; Jablczinsky, Zeitschr. phys. Chem., lxiv, 748: Spear, Jour. Am. Chem. Soc., xxx, 195; Bodensteln and Fink, Zeit. phys. Chem., lx, 1; Schleuderberg, Jour. Phys. Chem., xii, 583.

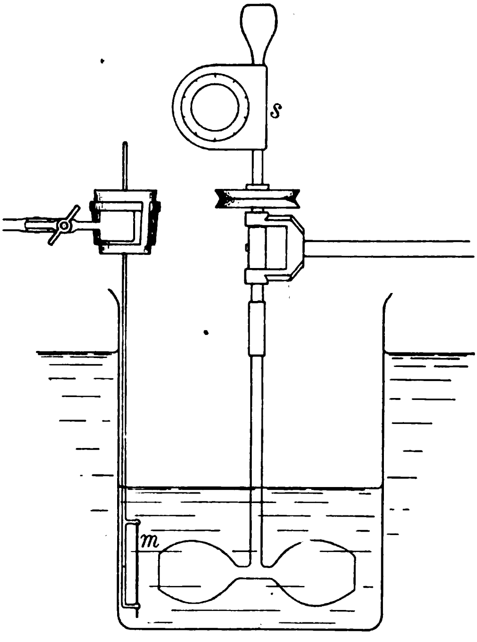
[§] Zeitschr. phys Chem., lvi, 689.

[‖] Ibid., lxi, 385; lxvii, 470.

[¶] Ibid., lxvi, 445.

Apparatus and Method.

For all of our experiments the apparatus shown in the figure was employed. The liquid, an aqueous solution of iodine or bromine with a large excess of the corresponding potassium halide, was contained in an ordinary beaker of about 11·5^{cm}



m, metal disk.
s, speed indicator.

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* Zeitschr. phys. Chem., viii, 76. † Ibid., li, 99.

diameter and 1¼ liters capacity supported in a thermostat containing about 50 liters of water. Most of the experiments were conducted at 25° ± 0·1°; one, however, at 35°. In the reaction vessel was a two-bladed glass stirrer of the form illustrated, the blades standing at an angle of about 45° to the vertical stem. The latter was attached to a brass shaft running in a bearing rigidly supported above the beaker and terminating in a horizontal pulley. A speed indicator provided with a bell which sounded every 100 revolutions was attached above the pulley and kept permanently in position.

The different metals were taken for experiment in the form of circular disks 40^{mm} in diameter and usually $0{\cdot}6^{mm}$ in thickness. For the experiments with mercury the disk was of pure gold heavily amalgamated. The holder for the disks was made of a thin glass rod provided at its lower end with three branches bent at right angles to the stem and tipped with an easily fusible glass, which grasped the disk at three points on its circumference. By softening one or more of these tips in the flame the disk was inserted so as to be firmly held with the minimum of contact between glass and metal. The glass stem was mounted in a cork which fitted into a brass socket in the form of a vertically slotted ring held by a stationary support above the beaker, so that the disk with its glass holder could be quickly removed from the apparatus or returned to exactly the same position. When in place the disk was held as shown in the figure, with its plane vertical, opposite the blades of the stirrer and 5–7^{mm} distant from the wall of the beaker, so that the liquid circulated freely behind it. Care was taken that the relative position of disk, stirrer, and beaker should be the same in all the experiments. The stirrer was driven by an electric motor of ⅛ horse power, and the different speeds obtained partly by interposing pulleys of various sizes and partly by adjustment of a rheostat in series with the motor. Variations in the speed of the stirrer were small and for the most part negligible in comparison with the other errors of experiment.

The rate of fall in concentration of the free halogen was determined by removing samples of the liquid with a pipette at definite intervals and titrating. From each two successive titrations the value of the expression $\frac{v}{t_2 - t_1} ln \frac{c_1}{c_2}$ was calculated and found, as required by the theory, to be practically constant throughout each series; c_1 and c_2 being the concentrations of the halogen at times t_1 and t_2, and v the volume of the solution, which remains constant during the interval in question.

From the point of view of the diffusion theory the mechanism of the reaction is as follows: The weight of bromine or iodine which reaches and reacts with the surface of the metal in the time interval *dt* is the amount which can diffuse through the adherent layer of liquid in that time, that is, according to Fick's law, it is proportional to the concentration fall across the layer. Owing to the rapidity of the chemical reaction the concentration of the halogen at the surface of the metal is always practically zero. At the outer surface of the layer it is equal to c, the concentration of the main solution. Hence the concentration fall is c, and if m is the total weight of available halogen in the solution,

$$-\frac{dm}{dt} = -\frac{d(cv)}{dt} = \mathrm{K}c,$$

where K is the velocity constant. Integrated for constant volume this gives

$$\mathrm{K} = \frac{v}{t_2 - t_1} ln \frac{c_1}{c_2},$$

the expression referred to above.

To assume that K is proportional to the area of the surface of contact, and to calculate upon this basis its value per unit of surface, is only permissible when the reaction takes place uniformly at every point of the surface. In the following tables this has not been done, since under the conditions of experiment the stirring could not have been equally effective on both sides of the disk.

Finally, it should be mentioned that the above equation, though a necessary consequence of the diffusion hypothesis, is by no means dependent upon it, since it is nothing but an expression of the *a priori* very probable assumption that the reaction velocity is proportional to the concentration of the halogen.

Experiments with Iodine.

The iodine solutions were initially about 0·03–0·045 equivalent normal, and contained in different cases from 100 to 800 grams of potassium iodide per liter (0·6 to 4·8 normal with respect to KI), the larger concentrations of potassium iodide being needed with the metals copper and silver to prevent the formation of a coating of insoluble iodide.

In the experiments with mercury and iodine the procedure was as follows: The gold disk was immersed in clean mercury, a known volume (500–520^{cc}) of the solution was placed in the beaker, and the stirrer adjusted to the required speed, after which a 20^{cc} sample was removed with a pipette and delivered into a glass-stoppered flask for subsequent titration. The disk was then lifted from the mercury, the excess shaken off, and at a definitely noted time inserted in the liquid. Exactly at the end of the chosen time interval the disk was removed from the solution, rinsed with water and again inserted in the mercury, and another sample of the solution taken for titration as before. This cycle of operations was repeated as often as desired, or

TABLE I.

Rate of Solution of Mercury in Iodine at 25°.

1. 100 g. KI per liter. $r=170$

c	Δt	v	K
0·0381	5	500	6·51
0·0356	6	480	6·30
0·0328	5·3	460	6·36
0·0304	5·7	440	6·25
0·0279	5	420	6·55
0·0257	5	400	6·59
0·0236		380	
		Average	6·43

2. 100 g. KI per liter. $r=240$

c	Δt	v	K
0·0378	10	500	8·71
0·0315	10	480	8·83
0·0260	10	460	8·82
0·0213	10	440	8·79
0·0172	10	420	8·87
0·0138	10	400	8·84
0·0109		380	
		Average	8·81

3. 200 g. KI per liter. $r=170$

c	Δt	v	K
0·0343	5	510	(6·92)
0·0319	10	490	7·13
0·0274	10	470	7·23
0·0233	10	450	7·26
0·0197	10	430	7·20
0·0165		410	
		Average	7·21

4. 200 g. KI per liter. $r=210$

c	Δt	v	K
0·0283	10	510	8·49
0·0238	10	490	8·64
0·0198	10	470	8·65
0·0163	10	450	8·49
0·0134	7	430	8·45
0·0116		410	
		Average	8·54

5. 200 g. KI per liter. $r=240$

c	Δt	v	K
0·0372	10	500	9·55
0·0305	10	480	9·51
0·0248	10	460	9·73
0·0199	10	440	9·63
0·0158	10	420	9·50
0·0125	10	400	9·38
0·00973		380	
		Average	9·55

6. 200 g. KI per liter. $r=300$

c	Δt	v	K
0·0346	10	520	11·33
0·0276	10	500	(12·92)
0·0211	10	480	11·34
0·0165	10	460	11·31
0·0127	10	440	10·82
0·00984	10	420	10·82
0·00751		400	
		Average	11·12

7. 400 g. KI per liter. $r=170$

c	Δt	v	K
0·0332	10	500	7·92
0·0282	10	480	8·10
0·0236	10	460	8·02
0·0197	10	440	8·25
0·0162	10	420	8·14
0·0132	10	400	8·39
0·01057		380	
		Average	8·14

8. 400 g. KI per liter. $r=240$

c	Δt	v	K
0·0439	10	500	10·78
0·0350	10	480	10·43
0·0276	10	460	10·61
0·0219	10	440	10·52
0·0171	10	420	10·48
0·0131	10	400	10·30
0·0100	14	380	10·23
0·00672		360	
		Average	10·48

until the volume had been reduced to 380^{cc}, which was thought to be a safe limit. Under these conditions the mercury goes into solution as the complex ion HgI_4'', and no mercurous salt appears to be formed. The samples were carefully titrated with N/20 sodium thiosulphate, using starch as indicator. The burette used had been certified by the Berlin Reichsanstalt.

In Table I are given the results of the experiments with mercury and iodine. The four columns taken in order contain: 1st, the concentration c, of the iodine in gram atoms per liter*: 2d, the time interval Δt (the same as t_2-t_1), in minutes; 3d, the volume v, in cubic centimeters; 4th, the velocity constant, K, as calculated by the equation above. The speed of stirring, in revolutions per minute, is denoted by r. In this and the following tables abnormal values of the constant, indicated by parentheses, have been disregarded in calculating the averages. It may be stated in this connection that the experiments recorded in this article include all that were made with the exception of preliminary experiments and a few affected by known errors.

On comparing the experiments carried out with like rates of stirring it is evident that the velocity of the reaction is greater the higher the concentration of the potassium iodide. This effect of the iodide will be equally conspicuous in the experiments with other metals, and will be discussed later. An increase in the rate of stirring also accelerates the reaction, as was to have been expected, the value of the constant being here approximately proportional to the 4/5 power of r.

To obtain the temperature coefficient of the reaction a single experiment was carried out at 35° with the following result:

Exp. 9.—Mercury and Iodine at 35°.

100 g. KI per liter. $r = 240$

K = (10·75), 11·68 11·35 11·50 11·53 11·59

Average 11·53

The ratio of this constant to that of experiment 2 gives 1·3 as the temperature coefficient for 10°. This is in sharp contrast with the usual value of $\frac{K_{t+10^\circ}}{K_t}$ for reactions in homogeneous systems, which is on the average about twice as large.

In the experiments with metals other than mercury the method followed only differed from that just described in that the metal disk, after its insertion into the solution, was allowed to remain in position until the close of the experiment, and the calculations were based upon the time intervals between successive fillings of the pipette. As the filling process occupied less than five seconds, the time was easily defined with sufficient accuracy.

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* Halogen concentrations are expressed in these units throughout this article.

TABLE II.

Copper and Iodine at 25°.

e	Δt	v	K
1. 400 g. KI per liter. r=170			
0·0347	10	500	7·71
0·0295	10	480	8·01
0·0248	10	460	7·95
0·0207	10	440	7·81
0·0172	10	420	8·00
0·0141		400	
		Average	7·90
		Corrected	7·95
2. 400 g. KI per liter. r=240			
0·0277	10	620	(8·78)
0·0239	10	600	9·86
0·0202	10	580	9·78
0·0169	10	560	9·69
0·01415	10	540	9·38
0·01181	10	520	9·53
0·00976	10	500	9·77
0·00796		480	
		Average	9·67
		Corrected*	9·98
3. 800 g. KI per liter. r=240			
0·0373	10	500	(9·91)
0·0304	10	480	10·20
0·0243	10	460	10·31
0·0192	10	440	10·15
0·0151	10	420	10·30
0·01167	10	400	10·10
0·00894		380	
		Average	10·21
		Corrected	10·27

TABLE III.

Silver and Iodine at 25°.

c	Δt	v	K
1. 400 g. KI per liter. r=180			
0·0405	10	500	8·35
0·0340	10	480	8·49
0·0283	10	460	8·14
0·0235	10	440	8·17
0·0193	10	420	7·88
0·0159	10	400	8·05
0·01285		380	
		Average	8·18
		Corrected	8·23
2. 400 g. KI per liter. r=240			
0·0443	10	500	10.17
0·0358	10	480	10·13
0·0287	10	460	9·79
0·0230	10	440	9·65
0·0183	10	420	9·69
0·0143	10	400	9·80
0·0111		380	
		Average	9·87
		Corrected	9·93

* The disk was below standard size both in diameter and in thickness.

Table II contains the results obtained with copper. .The disks were cut from a good quality of commercial sheet copper of the same diameter (40$^{\mathrm{mm}}$) as the gold mercury disk, but were slightly thinner at the outset, and during the experiment of course became still thinner, though the diminution of surface area from the latter cause was barely appreciable. From measurements made before and after the experiment the average thickness was estimated, and the necessary small correction calculated and applied to the mean value of the velocity constant. Where "corrected" values of the constant are given in this and the following tables the corrections have been made necessary by slight deviations of this kind from the normal dimensions. In cases where no correction is mentioned the disk was of the standard diameter and thickness.

A relatively high concentration of potassium iodide was found to be necessary in the work with copper. An experiment carried out with a concentration of 200 grams of the iodide per liter was a failure owing to the formation of a layer of insoluble cuprous iodide on the disk, which caused a rapid fall in the value of the constant. Even in the presence of 400 grams of potassium iodide per liter traces of such a film were noticed at the close of the experiment, although, as the table shows, fairly good constants were obtained. With 800 grams per liter no visible film was formed.

With silver the same difficulty was encountered. A concentration of 200 grams per liter of potassium iodide was not enough, and 400 grams per liter barely sufficient, to prevent a decided interference with the reaction by a coating of silver iodide on the metal. The disks were cut from a very pure sheet silver and were a little below the standard thickness, so that a correction had to be applied to the values of the velocity constant as in the case of copper. The results are given in Table III.

For the experiments with cadmium, recorded in Table IV, Kahlbaum's metallic cadmium was employed. This was cast into thick disks which were either rolled out to the proper thinness or ground down with emery. Experiment 1 was made with a disk of rolled metal, experiments 2 and 3 with cast and ground disks. The more crystalline nature of the latter was apparent after the action of the iodine; in fact, these two disks showed more roughening of the surface during the experiment than was the case with any of the other metals investigated. Even here, however, the roughening was comparatively slight, and seems to have affected the value of the constant but little, although experiment 2 shows a rise in the constant which may be due to this cause.

In order that the constants might be comparable with those obtained with mercury, the concentration of the potassium iodide in the work both with cadmium and with zinc was fixed at either 100 or 200 grams per liter, a much larger amount, in view of the ready solubility of the iodides of these two metals, than would otherwise have been needed.

The zinc disks used in the experiments of Table V were prepared by casting and grinding into shape from a sample of

TABLE IV.

Cadmium and Iodine at 25°.

1. 100 g. KI per liter. $r=170$

c	Δt	v	K
0·0364	5	500	6·36
0·0340	5	480	6·28
0·0318	5	460	(5·95)
0·0297	5	440	6·28
0·0276	5	420	6·27
0·0255	5	400	6·28
0·0235		380	
		Average	6·29
		Corrected	6·36

2. 100 g. KI per liter. $r=240$.

c	Δt	v	K
0·0329	5	500	8·57
0·0301	5	480	8·55
0·0274	5	460	8·60
0·0249	5	440	8·61
0·0214	6	420	9·03
0·0195	6	400	8·77
0·0170		380	
		Average	8·69

3. 200 g. KI per liter. $r=240$

c	Δt	v	K
0·0387	5	500	9·52
0·0350	5	480	9·56
0·0316	5	460	9·41
0·0283	5	440	9·52
0·0253	5	420	9·60
0·0224	5	400	9·74
0·0197		380	
		Average	9·56

metal of high purity, obtained from Kahlbaum. Experiments carried out in the same manner as those with cadmium and the other metals gave low and rapidly diminishing values of the constant. On examining the disk at the close of such an experiment a whitish semi-transparent film could be seen on its surface which proved to consist of zinc hydroxide, evidently formed by hydrolysis of the zinc iodide.

To obviate this difficulty the iodine solutions were made 1/100 normal with respect to sulphuric acid, after it had been proved by trial that sulphuric acid of this strength had no appreciable effect upon the very pure zinc of the disks. This expedient proved effective and at once gave normal values of the constant.

According to Schükarew,* the reaction between zinc and iodine is retarded by the presence of zinc iodide, but no figures are given in support of the statement. As the reaction is non-reversible such an effect would hardly be expected. To test this point, ten grams of zinc iodide, prepared by direct action of the two elements, was added at the outset to the solution in experiment 4, which in other respects was carried out exactly

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* Zeitschr. phys. Chem., viii, 81.

TABLE V.

Zinc and Iodine at 25°.

1. 100 g. KI per liter. $r=182$
$H_2SO_4=N/100$

c	Δt	v	K
0·0339	5	500	6·82
0·0316	5	480	7·32
0·0292	5	460	6·78
0·0270	5	440	6·99
0·0249	5	420	6·99
0·0228	5	400	7·27
0·0207		380	
		Average	7·08

2. 100 g. KI per liter. $r=240$
$H_2SO_4=N/100$

c	Δt	v	K
0·0371	5	500	8·59
0·0339	5	480	8·53
0·0309	5	460	8·64
0 0280	5	440	8·50
0·0253	5	420	8·80
0·0227	5	400	8·77
0·0202		380	
		Average	8·64

3. 200 g. KI per liter. $r=240$
$H_2SO_4=N/100$

c	Δt	v	K
0·0390	5	500	9·58
0·0353	5	480	9·71
0·0318	5	460	9·43
0·0285	5	440	9·72
0·0254	5	420	9·77
0·0225	5	400	9·60
0·0198		380	
		Average	9·64

4. 200 g. KI per liter. $r=240$
20 g. ZnI_2 per liter.
$H_2SO_4=N/100$

c	Δt	v	K
0·0402	5	500	9·49
0·0364	5	480	9·40
0·0329	5	460	9·27
0·0296	5	440	9·52
0·0264	5	420	9·55
0·0235	5	400	9·49
0·0207		380	
		Average	9·45

like experiment 3, using the same zinc disk, repolished. Unfortunately, through an oversight, the disk was not remeasured for experiment 4, so that the correction for diminished thickness can only be roughly estimated. Allowing for a correction of 0·04–0·08, the constants for experiments 3 and 4 agree to within the possible error of experiment, so that they can not be considered to confirm the observation of Schukarew. Owing to lack of time this point was not further investigated.

Bromine and Mercury.

Bromine dissolved in potassium bromide solution of sufficient strength reacts with mercury in much the same way as iodine. Such a solution has, however, a considerable bromine vapor pressure, and to measure the rate of reaction with a metal the evaporation of bromine must either be prevented or a correction must be applied. We have followed the latter method.

If the reaction with the metal is conducted and calculated as in the case of iodine, disregarding the evaporation of bromine, a fairly good constant is nevertheless obtained. The reason for this is obvious. The vapor pressure of the bromine is approximately proportional to its concentration in the solution, so that the rate of evaporation (for constant volume and constant free surface) must be proportional to the concentration, and will follow a mathematical expression of the same form as that which holds for the reaction with a metal. To correct the observed velocity constants it is therefore only necessary to subtract from them the velocity constants for the evaporation of bromine, as determined by separate blank experiments under like conditions.

TABLE VI.

Evaporation of Bromine.

Temperature 25° 400 g. KBr per liter. $r=240$

	C	C'	Δt min.	v cc.		K''
1.						
	0·02882	0·02767	15	500		4·49
	0·02418	0·02322	15	500		4·52
	0·02027	0·01946	15	500		4·37
	0·01707	0·01639	15	500		4·44
	0·01434	0·01377	15	500		4·09
	0·01218			500		
					Av.	4·38
2.						
	0·03262	0·03117	15	450		4·66
	0·02669	0·02550	15	450		4·83
	0·02171	0·02074	15	450		4·82
	0·01766	0·01688	15	450		(5·47)
	0·01406	0·01344	15	450		4·81
	0·01145	0·01094	15	450		4·75
	0·009335			450		
					Av.	4·77
3.						
	0·03526	0·03350	15	400		5·12
	0·02764	0·02626	15	400		5·14
	0·02165	0·02057	15	400		5·27
	0·01687	0·01603	15	400		4·91
	0·01333	0·01266	15	400		4·88
	0·01054			400		
					Av.	5·06

In practice the rate of evaporation of the bromine increases as the volume diminishes, owing to the increasing concavity of the surface of the solution caused by the rotary stirrer. The blank experiments recorded in Table VI were therefore carried out at constant volume, which was accomplished by adding to the liquid, immediately after withdrawing each sample for analysis, an exactly equal quantity of fresh potassium bromide solution. The resulting bromine concentrations were readily calculated, and are given in the column headed C′, while the concentrations directly indicated by the titrations are given under C. It will be observed that each C' denotes the concentration of the bromine at the beginning of a time interval Δt, the concentration at the end of the same interval being that value of C which is found in the table on the horizontal line next below, so that the equation by which the constant K'' is calculated takes here the form

$$K'' = \frac{v}{\Delta t}\, ln\, \frac{C_1'}{C_2}.$$

The analyses, both here and in the later experiments with mercury, were made by running each sample from the pipette into an excess of potassium iodide solution and titrating the iodine in the usual way.

From the mean values of K'' in the three experiments of Table VI the following values were obtained by graphic interpolation:

TABLE VII.

v	K'	$\log \frac{C_1'}{C_2}$ for $\Delta t = 1$
480	4·55	
460	4·70	0·0044
440	4·84	0·0048
420	4·96	0·0051
400	5·06	0·0055
380	5·15	0·0059

In the experiments with mercury and bromine the same method was followed as in those with iodine, but with attention to certain details which were previously not important. The pipette was filled immediately after each removal of the disk from the solution, and the time during which the disk remained out of the liquid was limited to exactly one minute in each case. The concentration changes due to loss of bromine during each such interval were calculated with the aid of the above values of $\log \frac{C_1'}{C_2}$. Table VIII contains the results of two parallel experiments on the rate of solution of mercury in bromine, with the necessary corrections applied. Under c are the bromine concentrations as determined by direct analysis, under c' the (calculated) concentrations at the moment of inserting the disk. The concentrations at the beginning and end of the same reaction period Δt are therefore given respectively by c' and that value of c which stands on the next line below. K' is the combined velocity constant for the solution of mercury and the evaporation of bromine. K is the velocity constant for the solution of mercury alone, obtained by subtracting from K' the corresponding value of K'', as given in Table VII.

TABLE VIII.

Mercury and Bromine.

Temperature 25° 400 g. KBr per liter. $r=240$.

c	c'	Δt min.	v cc.	K'	K
1.					
0·03133	0·03133	5	500	(15·77)	(11·22)
0·02658	0·02630	5	480	16·93	12·23
0·02188	0·02162	5	460	17·10	12·26
0·01780	0·01759	5	440	17·14	12·18
0·01434	0·01416	5	420	17·19	12·11
0·01142	0·01126	5	400	17·03	11·88
0·00900			380		
				Av.	12·13
2.					
0·02919	0·02919	5	500	(15·08)	(10·53)
0·02494	0·02469	5	480	17·22	12·52
0·02047	0·02025	5	460	17·79	12·95
0·01654	0 01634	5	440	17·27	12·31
0·01830	0·01313	5	420	17·13	12·06
0·01060	0·01046	5	400	17·32	12·17
0·00832			380		
				Av.	12·40

Owing to the method by which they were obtained these constants are necessarily somewhat more uncertain than the iodine constants. A comparison between the two is rather unsatisfactory on account of the presence in both cases of the large excess of soluble halide, and of the pronounced effects which the potassium iodide, and presumably also the potassium bromide, exert upon their respective reaction velocities. In Table I, experiment 8 is the one which approximates most closely to the conditions of the bromine experiments. If we take equal concentrations of the potassium halide as the basis of comparison, we must allow for the fact that the halide concentration was not the same in the two cases, but was greater in the bromine experiments in the ratio 166/119. Upon the assumption, based on the results of Table I, that a doubling of the concentration of the potassium iodide increases the constant by about ten per cent, the value of the iodine constant, at the same halide concentration as the bromine experiments, would be about 11·0. So compared, the reaction between mercury and bromine would appear to be about twelve per cent more rapid than that with iodine.

As an example of a reaction of a somewhat different type the rate of solution of mercury in cupric bromide was also determined. The presence of a sufficient quantity of potassium bromide was found to effectually prevent the formation of

TABLE IX.

Mercury and Cupric Bromide.

Temperature 25°   400 g. KBr per liter.

c mol/liter	Δt min.	v cc.	K	c mol/liter	Δt min.	v cc.	K
1. $r=160$				2. $r=215$			
0·0585		500		0·0774		510	
	10		4‘85		10		6·40
0·0529		480		0·0679		490	
	10		4·86		10		6·38
0·0476		460		0·0593		470	
	11		5·02		10		6·24
0·0420		440		0·0516		450	
	10		4·92		10		6·29
0·0373		420		0·0446		430	
	10		4·96		10		6·27
0·0330		400		0·0382		410	
	10		4·94		10		6·19
0·0290		380		0·0326		390	
		Av.	4·93			Av.	6·30

insoluble bromides, and the reaction was followed by adding samples of the liquid to a large excess of potassium iodide and titrating the iodine set free. If the solution is exposed to the air throughout the experiment some oxidation of the cuprous salt occurs, as the steady fall of the constant in the following preliminary experiment will show:

400 g. KBr per liter. $r = 220$.

K = 6·59,   6·54,   6·23,   6·17,   5·62,   5·79.

This was avoided in the experiments of Table IX by saturating the cupric bromide solution with carbon dioxide at the outset and conducting, throughout the experiment, a rapid current of the gas into the upper part of the reaction vessel, so that the liquid was covered at all times by a layer of carbon dioxide. Under these conditions, as the results indicate, little or no oxidation took place.

Discussion.

In Table X the values of the velocity constants are summarized for convenient comparison. The agreement between the constants obtained for different metals under like conditions is unmistakable, and is especially striking with the metals mercury, cadmium and zinc, which show a maximum variation of less than two per cent. This can hardly be an accident and points strongly to the conclusion that the reaction velocity is independent of the metal. As compared with mercury the constants for copper and silver are uniformly slightly lower, the largest difference being about five per cent, which is more than can reasonably be ascribed to experimental error alone.

The difficulty encountered in the work with copper and with silver in entirely preventing the formation of coatings of insoluble iodide upon the metal at once suggests itself as a probable explanation of the lower constants. As stated above,

TABLE X.

Summary of Velocity Constants.

A.

Iodine with Various Metals.

r revs. per min.	Concentration of KI grams per liter.			
	100	200	400	800
170	6·43 (Hg) 6·36 (Cd)	7·21 (Hg)	8·14 (Hg) 7·95 (Cu)	
180	7·03* (Zn)		8·23 (Ag)	
210		8·54 (Hg)		
240	8·81 (Hg) 8·69 (Cd) 8·64 (Zn)	9·55 (Hg) 9·56 (Cd) 9·64 (Zn)	10·48 (Hg) 9·98 (Cu) 9·93 (Ag)	10·27 (Cu)
300		11·12 (Hg)		

* $r=182$.

B.

Bromine with Mercury.

$r=240$	400 g. KBr per liter.	$K=\begin{cases}12{\cdot}13\\12{\cdot}40\end{cases}$

C.

Cupric Bromide with Mercury.

$r=160$	400 g. KBr per liter	$K=4{\cdot}93$
$r=215$	400 g. KBr per liter	$K=6{\cdot}30$

traces of such coatings were observed in some of the experiments included in the table, and it is by no means certain that their effect was wholly absent even when no sign of a coating was detected, and the value of K was fairly constant. Further evidence on this point is brought out in the two following tables.

Table XI shows the increase in K with the rate of stirring as measured by the value of n in the equation $\frac{K_1}{K_2} = \left(\frac{r_1}{r_2}\right)^n$, applied to each pair of comparable experiments carried out with one and the same metal. It will be observed that nearly all of the constants in Table X have been used in these calculations, including five of the six which stand alone in Table X and hence can not be directly compared with any others. This is important because a comparison of the values of n affords the best available test of the concordance between these isolated constants and the others.

TABLE XI.

Influence of Rate of Stirring.

Metal	Table	Experiments	*K*		*n*
Hg	I	1 & 2	6·43,	8·81	0·91
	I	3 & 5	7·21,	9·55	0·82
	I	4 & 6	8·54,	11·12	0·74
	I	7 & 8	8·14,	10·48	0·73
Cu	II	1 & 2	7·95,	9·98	0·66
Ag	III	1 & 2	8·23,	9·93	0·65
Cd	IV	1 & 2	6·36,	8·69	0·90
Zn	V	1 & 2	7·03,	8·64	0·75
Hg in $CuBr_2$	IX	1 & 2	4·93,	6·30	0·83

The values of *n* for copper and for silver are the lowest in the table. Except for these the agreement is about as good as could be expected; first because *n* is in all probability not a constant but variable with the conditions of concentration, etc., and second because *n*, for mathematical reasons, is rather sensitive to variations in K.

The effect upon the reaction velocity of doubling the concentration of the potassium iodide is shown in Table XII, where the ratios of the constants are given for such pairs of experiments as differed only in this respect. Here again copper shows a distinct difference in behavior from the other metals, silver not being represented in the table. The difference is unexpectedly large, but in the absence of other data to confirm it, nothing more than a qualitative significance can be attached to this single result.

TABLE XII.

Influence of Concentration of Potassium Iodide.

Metal	Table	Experiments	*K*		Ratio
Hg	I	3 & 1	7·21,	6·43	1·12
	I	5 & 2	9·55,	8·81	1·08
	I	7 & 3	8·14,	7·21	1·13
	I	8 & 5	10·48,	9·55	1·10
Cu	II	3 & 2	10·27,	9·98	1·03
Cd	IV	3 & 2	9·56,	8·69	1·10
Zn	V	3 & 2	9·64,	8·64	1·12

These comparisons serve to emphasize both the close agreement in the reaction velocities of mercury, cadmium and zinc, and the consistent though usually small deviations shown by copper and silver. The latter, however, are all explainable upon the assumption that the reaction is retarded to a slight extent by the presence of traces of the solid iodide at the contact surface. This explanation is a probable one and in the opinion of the writers may reasonably be accepted. We may conclude, in other words, that not mercury, cadmium, and zinc only, but *all the five metals investigated react with iodine at practically the same rate.*

Unless we accept the diffusion theory there seems to be no reason why these reaction velocities should be the same. But even if the above result should be found to hold for a large number of metals, it would not constitute conclusive proof that the diffusion of iodine is, as it appears to be, the determining factor. Evidence of a more direct nature is needed upon this point.

As shown above, a doubling of the concentration of the potassium iodide accelerates the reaction by about ten per cent. According to the diffusion theory such an acceleration might be due to an increase in (*a*), the rate of diffusion (here that of the iodine), or to a decrease in (*b*), the average thickness of the unstirred layer, or to both together. While (*a*) is in general directly measurable, little can be predicted about (*b*) except that it would vary with the properties, especially the viscosity, of the liquid. It seems, however, permissible to assume that in the majority of cases the changes in (*a*) would predominate over those in (*b*), and especially here, since the viscosity of strong solutions of potassium iodide at 25° varies but little with the concentration.[*] According to this view the rate of diffusion of iodine, or more accurately, that of potassium triiodide,[†] ought to show a distinct increase with the concentration of the potassium iodide.

As we have been unable to find any published data which either confirm or disprove this conclusion, we have carried out a qualitative test by comparing in two Nessler tubes of the same dimensions, clamped side by side in a large water bath, the rate at which the color spread from a lower layer of iodine in potassium iodide into an upper layer of pure potassium iodide of the same strength. The potassium iodide solutions in the two tubes contained respectively 25 and 400 grams of iodide per liter, and the iodine concentrations (the same in both tubes) were similar to those used in the previous work. Several repetitions of the experiment gave the same result. After a few hours a difference was visible in the extent to which the brown color had progressed beyond the initially sharp boundary, and in every case it was the stronger solution in which the diffusion appeared to be most rapid, thus confirming the conclusion drawn above with the aid of the diffusion theory. A confirmation based upon quantitative measurements would of course be much more satisfactory, and an attempt will be made by one of us in the near future to obtain quantitative evidence on this question. The result obtained is interesting in that it seems to be an exception to the rule of Abegg and Bose* according to which an electrolyte diffusing in the presence of a large excess of a salt with like cation tends to assume the velocity of its own anion. As the electrically measured velocity of I_3' ion is much less than that of K^+ ion†, a retardation would be expected in the present case instead of the observed acceleration.

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[*] According to W. W. Taylor and C. Ranken (Proc. Roy. Soc. Edinburgh, xxv, 231) the viscosities of 1 and 3-normal KI at 25° are 0·467 and 0·459 respectively, that of water at the same temperature being 0·501.

[†] With the aid of the equilibrium constant of the reaction $KI_3 \rightleftharpoons KI + I_2$, ($k = 0{\cdot}0014$ at 25°), determined by Jakowkin (Zeitschr. phys. Chem. xx, 19), it may easily be calculated that in no experiment in the above tables did the proportion of free iodine exceed a few tenths of one per cent of the total iodine, i.e., that indicated by thiosulphate. A similar calculation based on Jakowkin's data for bromine shows that in the experiments of Table VIII the tribromide bromine formed in all cases more than 98 per cent of the total bromine, so that here too the diffusion velocity would be practically that of the tribromide.

We have still to consider the application of the diffusion theory to the explanation of the observed reaction velocities of mercury with iodine, bromine, and cupric bromide respectively. The values of the iodine and bromine constants, for a potassium iodide or bromide concentration of 3·4 normal and stirring at 240 revolutions per minute, were compared on page 249. A correction for difference in the rate of stirring permits the cupric bromide constants of Table IX to be included in the comparison, which gives, for the approximate ratio of the reaction velocities, iodine 11·0, bromine 12·3, cupric bromide 6·9. Of the three solutions corresponding to these constants the last two would have practically the same viscosity; that of the iodine solution, judging by the viscosities given by Taylor and Ranken‡ for 3-normal solutions of potassium bromide and iodide, would be slightly lower. The difference between the iodine and bromine constants is therefore in the wrong direction to be explained by difference in the thickness of the unstirred layer, so that we must conclude, first, that the rate of diffusion of potassium tribromide is somewhat greater than that of potassium triiodide, at least in the concentrated solutions here used, and second, that cupric bromide diffuses decidedly slower than either. Both of these conclusions can be tested by direct measurement, but at present experimental confirmation is lacking. Both however are plausible, especially the last, which is in full agreement with the slow rates of diffusion of copper salts in general as compared with potassium salts.

We are far from regarding the evidence presented above as in any way conclusive in favor of the diffusion theory as applied to the reactions in question, but the fact that it accounts for the results obtained, and so far as yet shown leads to no inconsistencies, would seem to justify its retention for the present in dealing with reactions of this class. The work will be continued along similar lines.

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* Zeitschr. phys. Chem., xxx, 551.

† See Burgess and Chapman, Jour. Chem. Soc., lxxxv, 1305.

‡ Proc. Roy. Soc. Edinburgh, xxv, 231.

Summary.

1. The rates of solution of the metals mercury, cadmium, zinc, copper, and silver, in aqueous iodine solutions containing a large excess of potassium iodide, have been measured at 25° and shown to be practically equal, a slight difference observed with copper and silver being in all probability due to accumulation of the solid iodide at the contact surface.
2. The temperature coefficient for 10° (between 25° and 35°) is about 1·3.
3. An increase in the concentration of the potassium iodide produces a marked acceleration of the reaction.
4. Mercury dissolves in bromine in the presence of potassium bromide slightly faster than in iodine, but in cupric bromide much more slowly, the ratios of the velocities being about 12·3 : 11·0 : 6·9.
5. The reaction velocity was found to be proportional, on the average, to the 4/5 power of the rate of stirring.
6. So far as can be decided from the data at present available, the diffusion theory of Noyes, Whitney, and Nernst gives a satisfactory explanation of the results obtained.

Art. XX.—*A New Cretaceous Bauhinia from Alàbama;*[*]
by Edward W. Berry.

In a recent note in Torreya[†] a new Cretaceous *Bauhinia* was described from the Magothy formation of Maryland, and the writer at that time took occasion to call attention to the various fossil species, seven in all, ascribed to this genus of the Cæsalpiniaceæ with their respective ages. Still more recently Cockerell has described[‡] an additional species from the Florissant, Colorado, shales which he calls *Bauhinia pseudocotyledon.* While the genus is known from both the Cretaceous and the Tertiary of Europe, no Tertiary species had heretofore been described from North America, although the Cretaceous forms are exceedingly well marked and characteristic. The species described by Cockerell is not as characteristic either in outline or venation as might be desired and should possibly be compared with other genera of the Cæsalpiniaceæ or Mimosaceæ; at the same time its relations are sufficiently obvious to indicate the presence of a warm temperate element in the Florissant flora. Lesquereux insisted that these deposits which Cockerell calls late Miocene were the same age as the Green River shales, a position no longer tenable; and in this connection it is interesting to recall that they were originally called Pliocene by Dr. A. C. Peale.

The occasion for the present note, however, is furnished by the discovery of a large and striking species in the Tuscaloosa formation of Alabama which may be characterized as follows:

Bauhinia alabamensis sp. nov.

Bilobate leaves of medium and large size, 8^{cm} to 15^{cm} in greatest length by 11^{cm} to 18^{cm} in greatest breadth. Medial sinus rather broad and rounded, reaching two-thirds of the distance toward the base or even more. Lobes somewhat reniform in outline, sublobate, rounded above and with three broadly rounded sublobes on the outer side, the entire margin curving upward and inward from the lower and largest lobe to the truncate or deeply cordate base, which appears to be slightly peltate in some specimens. Midrib comparatively slender, $1{\cdot}7^{cm}$ to $3{\cdot}^{cm}$ in length, running to the base of the medial sinus and sending off two branches in its upper part, one on each side, which curve upward parallel with the inner margin to join inwardly directed branches from the lateral primaries. Main lateral primaries stout, sending two or three upwardly directed branches inward and three or four longer less oblique branches outward, the latter forking and forming broad arches in the lateral lobes. One or two additional lateral primaries on each side take their origin from the common point of divergence of the palmate or bilateral system of venation of this species and are confined to the lower lateral lobe on each side along the margin of which their branches arch.

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[*] Published by permission of the Director, U. S. Geol. Surv.

[†] Berry, Torreya, vol. viii, p. 218, 1908.

[‡] Cockerell, ibid., vol. ix, p. 184, 1909.

This ornate and butterfly-like species of *Bauhinia* is not uncommon in the sandy clays of the Upper Tuscaloosa near Havana in Hale County, Alabama, but owing to the unsatisfactory character of the matrix, which is too sandy for good collecting, and also to the fact that the plant remains had evidently been in the water a long time before entombment, only fragmentary specimens were secured. These represent, however, all parts of the leaf and are complete enough to serve as an entirely accurate basis for the complete leaf shown in the accompanying figure.

FIG. 1.

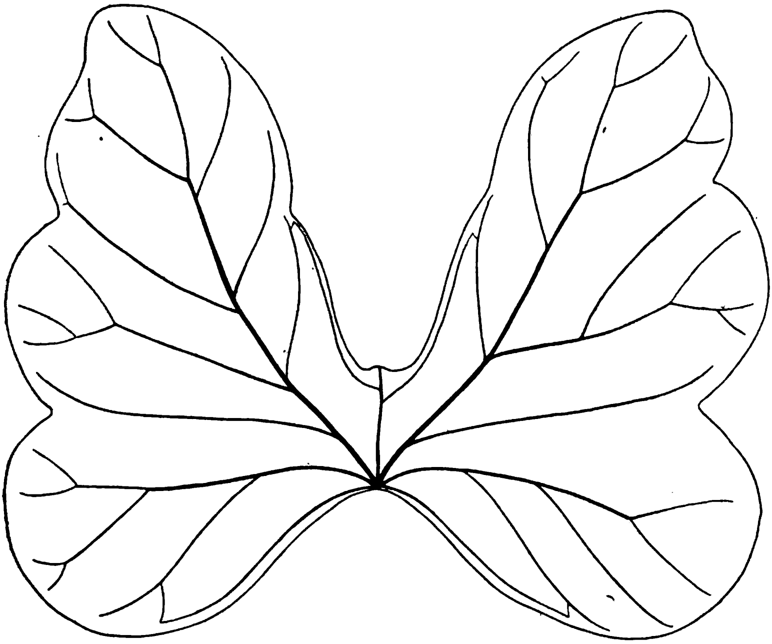

FIG. 1. **Restoration of *Bauhinia alabamensis* Berry, 4/7 nat. size.**

This species is markedly distinct from any of the fossil species hitherto known. In size and general appearance it suggests *Bauhinia cretacea* Newberry* of the Raritan formation in New Jersey, and it may well be a descendant of that species, which as time passed widened out and became sublobate. It differs from any existing species known to the writer in its great width and sublobate character, although several recent smaller-leaved species approach it in the latter respect, and it seems probable that if representative collections of the foliage of the recent forms showing the limits of specific variation were available for comparison, it would be found that a tendency toward the formation of sublobes was far from exceptional. Two recent species were noted as showing this marginal character. These are *Bauhinia hookeri* F. v. M. of Australia and *Bauhinia tomentosa* Linné of the West Indies.

The display of species of this modern tropical genus in the Upper Cretaceous of the Atlantic coastal plain is certainly remarkable, for it embraces very small and very large forms and shows a variety almost as great as that furnished by the existing species. Quite recently still another and very distinct species of *Bauhinia* was collected by the writer from typical Ripley strata in Alabama and this will be described upon a subsequent occasion.

Johns Hopkins University,
Baltimore, Md.

ART. XXI.—*Anhydrite and Associated Minerals from the Salt Mines of Central Kansas;* by AUSTIN F. ROGERS.†

IN this country anhydrite, the anhydrous calcium sulphate, seems to be a rather rare mineral. A year or so ago the writer found it in some abundance at several of the salt mines in central Kansas. So these must go on record as occurrences similar to the well-known localities in Germany and Austria where it is a common mineral. In characters and paragenesis the Kansas anhydrite resembles the foreign anhydrite.

The anhydrite was collected from the dump-piles of the salt mines at Kanopolis, Ellsworth Co., and at Lyons, Rice Co. At Kanopolis rock-salt is mined in one shaft at a depth of 795 feet and in another shaft at a depth of 805 feet. The layer of salt is about 11 feet thick. A log of the Lyons shaft and of a deep well at Kanopolis are on record‡ but the anhydrite evidently was not identified, as no record of it appears. At Lyons a 17-foot bed of salt occurs at the bottom of a shaft 1100 feet deep. At Kingman, Kingman Co., Prof. J. T. Willard of Manhattan also obtained anhydrite from the dump of a salt mine. Bailey and Failyer in their list of Kansas minerals* mention this occurrence of anhydrite, but it has evidently been overlooked, for no mention of it is made in any of the reports of the University Geological Survey of Kansas.

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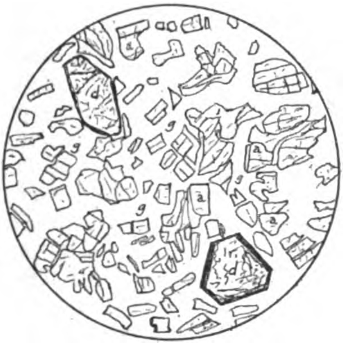
* Newberry, Fl. Amboy Clays, p. 91, pl. xliii, figs. 1–4 ; pl. xliv, figs. 1–3, 1896.

† Published by permission of the State Geologist of Kansas.

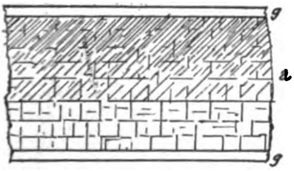
‡ Annual Bulletin on Mineral Resources of Kansas for 1898, pp. 93–4.

Fig. 1.



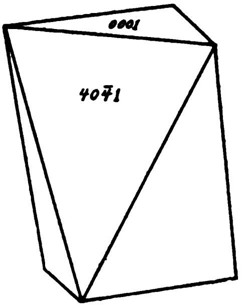
a, anhydrite; *d*, dolomite; *g*, gypsum.

Fig. 2.



a, anhydrite.
g, gypsum.

Fig. 3.



From an examination of the dump-piles it is evident that the anhydrite occurs in thin lenticular layers interbedded with shales, and probably has an appreciable vertical distribution. This is also true of the salt according to the shaft and well records cited above. Some specimens from the dumps show an intimate mixture of salt and anhydrite. The writer was also informed that at Lyons anhydrite occurs below the main salt bed. At the salt mines gypsum occurs in small quantities and probably only as a secondary mineral. The explanation of the association of anhydrite with the salt is based upon the experimental work of Rose and others. When sea-water is evaporated $CaSO_4.2H_2O$ is the first substance to crystallize out. On further evaporation NaCl forms and with it $CaSO_4$. That is, anhydrite instead of gypsum forms from a concentrated solution saturated with NaCl. Later magnesium and potassium chlorids and sulphates are formed. In the Kansas deposits these have been dissolved if ever they were formed.

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* Transactions Kansas Academy of Science, vol. xiii, p. 78, 1891-2.

The salt and anhydrite occur in the lower Permian. According to Plate V of the report on Kansas salt,* the salt-beds are between the Wellington and Marion formations. Not a single fossil was found on the saltmine dumps, and this is not strange when we consider the conditions under which these deposits were formed. From evidence gathered in various places it seems certain that throughout the northern hemisphere an arid climate prevailed in the Permian. The poverty of fossils, the occurrence of Red-beds, and the presence of extensive beds of gypsum and salt, all point to the fact that Kansas was like the rest of the northern hemisphere during Permian time. Now the occurrence of anhydrite with the salt is additional evidence that the Kansas Permian is like the Permian (Zechstein) of Germany during which time the salt-deposits of Stassfurt, Leopoldshall, Vienenburg, and Bernburg were formed. At all these localities anhydrite occurs with salt.

Anhydrite.—The massive anhydrite is a gray or reddish granular rock occurring in thin lenticular layers rarely over four inches thick. It resembles gypsum but is heavier (sp. gr. 2·9) and harder (h. 3½). A microscopic examination of the rock shows an aggregate of imperfect sub-angular squares and rectangles, with bright interference colors and parallel extinction. Some of the massive anhydrite gives off water in the closed tube. This points to the presence of gypsum, which is shown in a thin section (figure 1). The mineral with high relief marked *a* is anhydrite. The spaces between the anhydrite are filled with gypsum marked *g*, which has low relief, aggregate structure and low-order interference colors. The gypsum has evidently formed from the anhydrite by hydration. Dolomite is also present, marked *d*. Cleavable and fibrous anhydrite occurs in seams often an inch or more thick. The anhydrite has the typical pseudo-cubic cleavage and one of the cleavages is usually parallel to the plane of the seam. The seams are often fibrous in an oblique direction. The explanation of this is shown in figure 2, which represents a cross-section of a seam. The fibrous structure is due to polysynthetic twinning parallel to an oblique face. The twinning is probably secondary, as it apparently begins at one side of the seam and gradually causes the mineral to take on a fibrous structure. A few minute pseudcubic crystals of anhydrite were found in close association with halite. These are doubtless secondary and on account of the halite crystallized as anhydrite instead of as gypsum.

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*Annual Bulletin of the Mineral Resources for 1898.

Gypsum.—Gypsum is present as a subordinate mineral and apparently is always secondary. It occurs in some of the massive anhydrite as an alteration product (figure 1). Also coats seams of cleavable anhydrite but as sharply defined layers (figure 2). On the surface of some of the anhydrite specimens are small gray crystals of gypsum mixed with clay. These have evidently been formed since the material was thrown on the dump-piles.

Dolomite.—Dolomite occurs in minute crystals disseminated through some of the massive anhydrite (see *d*, figure 1). In habit the crystals are unusual, the forms being $(40\bar{4}1)$ and (0001) as represented in figure 3. Similar crystals occur in gypsum at Hall in the Tyrol.

Celestite.—A heavy reddish mineral, occurring in masses of imperfect tabular crystals and also in small fibrous forms in the cleavable anhydrite, proves to be celestite. This intimate connection with anhydrite would perhaps indicate that the celestite is a direct deposition from sea water.

Quartz.—Quartz occurs in small (2 or 3 mm.) pale reddish crystals imbedded in the massive anhydrite. It has the usual faces $(10\bar{1}1)$, $(01\bar{1}1)$, and $(10\bar{1}0)$ and the habit is like that of the Suttrop, Westphalia crystals.

Pyrite.—Pyrite is found in minute brown oxidized crystals in the anhydrite. It is coated with a yellow alteration product resembling copiapite.

Halite.—Halite occurs in clear cubic cleavages up to three or four inches in size. Negative crystals filled with a liquid and moving bubbles are common. A red fibrous halite occurs at Kanopolis., Halite is directly associated with anhydrite and is sometimes embeddded in it.

Careful search was made for the other Stassfurt minerals but none was found. A reddish fibrous mineral very much resembled polyhalite but proved to be celestite.

Stanford University, California,
December, 1909.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Purple Dye of the Ancients.*—In an address delivered at Frankfort a. M., P. **FRIEDLAENDER** has given an interesting account of the highly prized purple dye of the ancients, together with a solution of the mystery of its chemical nature. It appears that Greek and Roman literature supplies abundant information concerning the history of this dye, but the technical details of the lost art of applying it are almost wholly lacking. It is hardly possible that the process was a secret one, since it was employed by nearly all Mediterranean peoples in many localities, hence the lack of information seems to be due to the low social status of the dyers of ancient times. The species of mollusks employed in the preparation of this royal purple are well known, both from ancient descriptions and the remains of broken shells still existing in heaps at places where the dye was prepared, and it appears that the sea-snails or periwinkles now known as *murex brandaris*, *murex trunculus*, and *purpura haemostoma* were those chiefly used. It is known also that only a very small organ of the snail was utilized. From ancient statements concerning the value of the dyed material the calculation is made that the value of the dyestuff must have been something like $5,000 per pound.

Several previous investigators have attempted the study of this coloring matter, but without definite results, except that color tests seemed to indicate some analogy to indigo-blue or indigo-red. In undertaking a new study of the matter Friedlaender obtained a supply of mollusks from various Mediterranean zoological stations. After breaking the shells, the glands, which show no color in their original condition, were taken out, their contents were spread upon filter paper and exposed to sunlight for the development of the color. This material was then treated with hot dilute sulphuric acid in order to remove more soluble matters, and then the coloring matter was extracted with a high-boiling solvent, such as quinoline or benzoic ether, from which it was easily obtained pure by crystallization. The yield was very small, amounting to only 1·5 g. from 12,000 specimens of *murex brandaris*.

Upon analysis the remarkable fact was found that it contained much bromine, and it was established without doubt that the substance was 6,6, diabrom indigo, a compound already known which can be synthesized in several ways, and which could be manufactured at a price a thousand times less than its cost in times of antiquity. But it is hardly to be expected that it will be used at the present time, for it has a rather dull, reddish-violet color, which makes no marked impression upon modern eyes, and besides the tint can be reproduced by several thio-indigo derivations. Friedlaender says that we have thus lost one of our illusions ; but still he has observed that *murex trunculus* gives, besides this reddish-violet coloring matter, also a dark blue one, which results by oxidation, and not by the action of light, from a colorless body.

In spite of Friedlaender's verdict in regard to the royal purple, it still seems possible that the ancients may have been able to produce a really magnificent color by means of some lost method of combination or manipulation.—*Zeitschr. angew. Chem.*, xxii, 2321. H. L. W.

2. *The Purification of Water Supplies by the use of Hypochlorites.*—Dr. W. P. MASON has given an account of the use of bleaching powder or of sodium hypochlorite in the purification of water supplies. He says that those who have been opposed to this method must change their position on account of the results that have been obtained in France and England, as well as at the Chicago Stock Yards and with the municipal supply of Jersey City. In the latter case the dose of available chlorine used during the month of December, 1908, averaged approximately 0·03 grains per gallon, and has since been materially reduced. While using the above amount the daily counts of bacteria per c.c. were as follows :

	Raw Water	Treated Water
Maximum	1600	30
Minimum	240	0
Average	559	2·7

No part of this minute dose of hypochlorite reaches the consumer, and protection against pathogenic germs appears to be assured. It is not expected that the process will take the place of filtration, because it does not improve the physical appearance of a water, but as an adjunct to a filter plant there can be no question of its usefulness in times of emergency, and it can be depended on to render a somewhat polluted water safe for domestic purposes at a moderate price.—*Proc. Amer. Phil. Soc.*, xlviii, No. 191. H. L. W.

3. *Allen's Commercial Organic Analyses*, edited by HENRY LEFFMANN and W. A. DAVIS. Fourth edition, entirely rewritten. Philadelphia, 1909 (P. Blakiston's Son & Co.).—The first volume of a complete revision of Allen's great work will be welcomed by all commercial analysts. The revision is being undertaken by specialists in the various branches of the subject, an arrangement which will undoubtedly lead to a presentation of the most recent and best methods. The present volume contains an introduction dealing with general operations and the determination of physical properties of substances, and takes up the subjects of alcohols, malt and malt liquors, wines and potable spirits, yeasts, neutral alcoholic derivatives, sugars, starch and isomers, paper and paper-making materials, and acid derivatives of alcohols. The contributors to this volume are E. Frankland Armstrong, Julian L. Baker, William A. Davis, G. C. Jones, Henry Leffmann, Emil Schlichting and R. W. Sindall. Two of these contributors and several others who will assist in the prepa-

ration of subsequent volumes are Americans, so that the work will have an international character. The complete work will consist of eight volumes, which will be issued rapidly. H. L. W.

4. *Introduction to Physical Chemistry;* by HARRY C. JONES. 12mo, pp. xv + 279. New York, 1910 (The Macmillan Co.).—This book is practically an abbreviated edition of the author's Introduction to Physical Chemistry and is designed for a shorter college course in physical chemistry. Much of the text and many figures are taken from the larger book. The six chapters in the book are on the atom, gases, liquids and solids, solutions, thermochemistry and photochemistry, electrochemistry, and chemical dynamics and equilibrium.

It will probably find considerable use in the colleges.

H. W. F.

5. *Change from Positive Reflection to Negative through Pressure.*—O. LUMMER and K. SORGE have repeated Lord Rayleigh's observations on this subject, moved, probably, to a consideration of the subject by the remark of Rayleigh, that in the study of surface conditions by means of light much can be learned of the constitution of matter. The authors of this paper show that the ellipticity at a reflecting surface can be appreciably changed by a mechanical change of the medium without influencing the reflecting surface.—*Ann. der Physik*, No. 2, 1910, pp. 325–342.

J. T.

6. *Study of Gaseous Suspensions.*—MAURICE DE BROGLIE refers to the Brownian movement in fluids and calls attention to analogous movements of suspended particles in air or gases. He describes an ultra microscopic arrangement which he uses to study smoke particles. He discusses the effect of an electric field, influence of weight, and the relations of the movements observed to Brownian movements. In smoke, he finds particles of which the radius lies between $\mu\mu$ and a hundredth of $\mu\mu$.—*Physik. Zeitschrift*, Jan. 15, 1910, pp. 33–39. J. T.

7. *Constitution of the Electric Spark.*—The work of Schuster and Hemsalech has been continued by T. ROYDS, under the advice and suggestion of Schuster and Rutherford. The method of observation consisted in focussing the spark upon a rapidly revolving photographic film. The velocities of metallic vapor caused by the spark between different terminals are given in a table. In general these velocities are within $10^3 \frac{m}{s}$. The author shows that the vaporization of the metallic electrode is simultaneous with the pilot or initial spark. Two simultaneous velocities were obtained in the case of calcium vapor.—*Phil. Mag.*, Feb., 1910, pp. 285–290. J. T.

8. *Cadmium Amalgams and the Weston Normal Cell.*—In a communication from the National Physical Laboratory, F. E. SMITH reviews the work of previous writers on this subject and submits his own measurements. There are many suggestions deduced from his work. Among them is the advice that the 12½ per cent amalgam be replaced by a 10 per cent amalgam.—*Phil. Mag.*, Feb., 1910, pp. 250–276. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Florida State Geological Survey;* E. H. SELLARDS, Geologist.. Second Annual Report, 1908–9. Pp. 296, 19 pls., 5 figs., geologic and topographic map in pocket.—This includes the following: 1. A Preliminary Report on the Geology of Florida; by GEORGE CHARLTON MATSON and FREDERICK G. CLAPP, prepared in coöperation between the United States Geological Survey and the Florida State Geological Survey under the direction of THOMAS WAYLAND VAUGHAN. 2. Topography and Geology of Southern Florida; by SAMUEL SANFORD.—Scattered papers and reports dealing chiefly with the coast line have heretofore been the basis of our knowledge of Florida geology. We now have, however, a preliminary report on the geology of the whole state, together with a topographic and geologic map. In view of previous opinions, the reader of this report will be interested to learn that the geologic structure of Florida is diversified, not simple; and that corals, instead of being the chief agent in the formation of the bed rock of the state, have really played a minor rôle: have always been limited to the extreme southeastern part of the peninsula. "There appears to be no reason to suppose that reefs have existed on the west coast or north of the north line of Palm Beach County on the east coast" (p. 40).

Florida is a region of low plains and deeply dissected uplands. The state as a whole has an elevation of less than 100 feet. The topographic map shows an area in the southern part of the state 150 miles long by 100 miles in width, with an altitude of less than 50 feet; and one of the longest rivers in the state, the St. Johns, is nowhere more than 30 feet above the tide. On the other hand, detached areas along the Georgia-Alabama line reach 250 feet and "small areas may exceed 300 feet." The drainage is consequent and superimposed, and includes excellent illustrations of extended streams. The imperfectly drained areas contain thousands of lakes occupying either solution cavities or shallow basins due to unequal deposition of sands. Lakes of the former type predominate in the more elevated portion of the peninsula, and the rate of solution by ground water in this area is found by Sellards to equal the annual removal of 400 tons per square mile. The Everglades, 22.4 feet above tide, are found to be almost completely surrounded by a rim of rock; and are believed by Mr. Sanford to be similar in origin to the Dismal Swamp of Virginia.

In structure Florida is "the southern extension of the coastal plain, and its history, in general, has been the same." An uplift similar to the Cincinnati arch has raised the lower Oligocene more than 100 feet above the sea.

The geological formations include Tertiary and Quaternary; the oldest rocks belong to the Oligocene Period, and include the

Vicksburg and Appalachicola groups. Three of the four formations of the latter are believed to have been deposited contemporaneously. Two formations have been distinguished in the Miocene, five in the Pliocene, including the Lafayette. The various formations are discussed in detail, pp. 50–162. The Pleistocene geology is unusually interesting here because of abundant proof of several elevations and depressions of the peninsula, including movements going on at the present time. Modified drainage, sea cliffs and terraces are topographic features abundantly represented.

The report of Samuel Sanford on the Topography and Geology of Southern Florida (pp. 177–231) is the first attempt at a complete geological description of this area. The studies include the Everglades, the Coastal Plain, and the reefs and keys along the line of the Florida East Coast Railway. Owing to the recent deposition of the beds and their more recent elevation, the topography of this area is in a stage of infancy. "Drainage is defective, sloughs, shallow ponds and lakes abound. Most of the interior is a swamp, there are no well-defined river systems nor stream valleys, and some of the short rivers that flow from the Everglades into the Atlantic are, where bed rock comes a few feet above tide level, characterized by rapids in their upper courses." The author agrees with Dall that "the present Florida mainland is but the top of a vastly greater submarine plateau, the southeastern and southern edges of which are near the present shore line, the western edge many miles to the west." One of the striking features of southern Florida is the absence of rock outcrops over wide areas where the ledge is but a few feet below the surface. Part of the extensive mantle of sand which so effectually conceals the bed rock has been carried down the Atlantic coast by waves and currents, and part of it comes from the disintegration of arenaceous limestones and marls.

The State Geologist discusses the origin, distribution and commercial importance of phosphates, diatomaceous earth, fullers' earth, and other economic products. H. E. G.

2. *Report of Topographic and Geologic Survey Commission of Pennsylvania, 1906–1908.* Pp. 375, 21 plates and 21 figures, Harrisburg, 1908.—The First Geological Survey of Pennsylvania under the direction of H. D. Rogers was organized in 1836, and issued reports in 1836, 1838, 1840, 1841, and 1842, with two volumes of final reports in 1858. The Second Geological Survey, organized in 1874 under the direction of J. P. Lesley, was continuously in operation from 1874 to 1887, issuing 77 volumes, 38 atlases, in addition to a "grand atlas." Three volumes of the final report of this survey were issued in 1893–1895. In 1899 a topographic and geologic survey was organized to work in coöperation with the United States Geological Survey. Under these auspices work was carried on under the general direction of M. R. Campbell until 1894, when the general supervision was placed in the hands of George H. Ashley. The results of the work have been published from time to time by the United States Geologi-

cal Survey. Under present conditions, accuracy and completeness in topographic and geologic work have reached a much higher level than was possible under the conditions controlling the earlier state surveys.

The present volume will doubtless be welcomed by the people of Pennsylvania as well as by students of geology in general, because it contains within a reasonable compass a discussion of the salient features of the geology of the state. By means of this General Review it is possible now to get a clear conception of Pennsylvania geology, stratigraphic and physiographic, as well as economic, and including recent discoveries, without reading through a mass of detailed and technical description. The general geologic report has been largely written by R. W. Stone, the pre-Pennsylvanian stratigraphy by Charles Butts, the petroleum and gas report by M. J. Munn. H. E. G.

3. *Virginia Geological Survey;* THOMAS L. WATSON, Director. Bulletin No. II–A; The Cement Resources of Virginia, West of the Blue Ridge, by RAY S. BASSLER, with an Introductory chapter on the Materials and Manufacture of Hydraulic Cements, by EDWIN C. ECKEL. Pp. xii, 309, 30 plates, 30 figures. Charlottesville, 1909.—The development of the cement industry in Virginia justifies the publication of the present report, which, however, is more than an economic paper, and includes a valuable report (pp. 136–185), chiefly stratigraphic, on the geology of western Virginia, a region which has heretofore been inadequately studied. H. E. G.

4. *Illinois State Geological Survey;* H. FOSTER BAIN, Director. Bulletin 11; Physical Features of the Des Plaines Valley, by JAMES WALTER GOLDTHWAIT. Pp. x, 103, 9 plates and 21 figures. Urbana, 1909.—Attention has previously been called to the admirable series of Educational Bulletins dealing with the geology of the state of Illinois, planned by the Illinois Geological Survey. This present bulletin is fully up to the standard of the others, and amply justifies the labor expended. Too little attention has been paid by state and national surveys to the needs of teachers and general readers; and it is hoped that this series, dealing in a more or less untechnical way with interesting type localities, will encourage other organizations to undertake a similar work. H. E. G.

5. *Geology and Water Resources of the Northern Portion of the Black Hills and Adjoining Regions in South Dakota and Wyoming;* by N. H. DARTON. Professional Paper, U. S. G. S., No. 65, 1909. Pp. 105, 24 plates, 15 figures.—Several previous papers and reports by Mr. Darton, dealing with the Black Hills and the surrounding region, have presented the geology of this interesting area in an exceptionally attractive manner. These papers of Darton's taken in connection with the reports by Professor Jaggar and Professor Irving, and the earlier report of Newton and Jenney, constitute a body of geologic literature available for few areas in the United States.

The present report includes part of the material previously published, as well as much additional matter; and, taken in connection with the author's report on the southern Black Hills, will remain as the authoritative work on this area. This paper, including as it does the topography, general geology, stratigraphy, structure, geological history, as well as a discussion of the water resources, mineral resources, and climate, all parts of it well written and well illustrated, may serve as a type publication if the United States Survey desires to be directly helpful to teachers and students, and to the increasing body of readers who are interested in geography, physiography, and general geological description, rather than in details of paleontology, petrography and economic geology. H. E. G.

6. *Biological Survey of Michigan: An Ecological Survey of Isle Royale, Lake Superior;* prepared under direction of CHARLES C. ADAMS. Pp. xiv and 422, 63 figures.—The following papers are included in Part I of this report: 1. Isle Royale as a Biotic Environment; Dr. Charles C. Adams. 2. The Ecological Relations of the Invertebrate Fauna of Isle Royale, Michigan; Dr. H. A. Gleason. 3. The Ecological Distribution of the Birds of Isle Royal, Lake Superior; Otto McCreary. 4. The Fall Migration of Birds at Washington Harbor, Isle Royale, Lake Superior; Max Minor Peet. 5. The Ecological Succession of Birds; Dr. Charles C. Adams. 6. The Coleoptera of Isle Royale, Lake Superior, and their Relation to the North American Centers of Dispersal; Dr. Charles C. Adams.

Part II contains the following annotated lists: 1. Notes on the Vegetation of Isle Royale, Michigan; W. P. Holt. 2. Annotated List of Certain Isle Royale Invertebrates; Dr. Charles C. Adams. 3. Annotated List of the Mollusca of Isle Royale, Michigan; Bryant Walker. 4. Report on the Isle Royale Orthoptera of the 1905 Expedition to Isle Royale; A. P. Morse. 5. Neuropteroid Insects from Isle Royale, Michigan; Dr. James G. Needham. 6. Diptera of the 1905 University Museum Expedition to Isle Royale; Professor James S. Hine. 7. Annotated List of Isle Royale Hymenoptera; E. S. Titus. 8. The Ants of Isle Royale, Michigan; Dr. Wm. M. Wheeler. 9. The Cold-Blooded Vertebrates of Isle Royale; Dr. A. G. Ruthven. 10. Annotated List of the Birds of Isle Royale; M. M. Peet. 11. Notes on Isle Royale Mammals and their Ecological Relations; Dr. Charles C. Adams. H. E. G.

7. *The University Geological Survey of Kansas*, ERASMUS HAWORTH, State Geologist. Vol. ix, Special Report on Oil and Gas. Pp. xiv, 586, with a geological map, 1 chart, 107 plates, and 8 figures. Topeka, 1908. Sent when applied for upon the receipt of 30 cents postage.—This large volume is devoted to a special report on the petroleum and natural gas of Kansas, and has been prepared by the state geologist and his assistants. The great economic development of these industries in the mid-continental field of Kansas and Oklahoma within the first few years (see also xxviii, 560) gives a peculiar interest to this volume. It

opens with a historical chapter in regard to the discovery of oil, particularly in Kansas, from 1860 down to the present time, the third or most important period beginning with 1890. Chapters follow on the history of field work, the stratigraphy, etc., while the subjects of the chemical composition of both gas and petroleum are taken up in much detail. J. W. Beede and A. F. Rogers (pp. 318–389) contribute an account of faunal studies from the Coal Measures, and E. H. Sellards chapters on fossil plants (pp. 386–480) and on fossil cockroaches (pp. 501–541).

8. *Das Antlitz der Erde;* von EDUARD SUESS. Third volume, second half; conclusion of the entire work. Pp. iv + 789, 55 text illustrations, three tables and five colored maps. Accompanied by an index of 153 pp. bound separately.—The publication of this final volume of "The Face of the Earth" marks the consummation of the life work of the distinguished leader of European geology, the completion of a labor so important and so vast that at the recent annual meeting of the Geological Society of America a resolution of congratulation and admiration signed individually by the entire body of geologists present was transmitted to its author.

In this work, the publication of which has extended over a generation, the entire geological literature of the past century of both the old and new worlds has been drawn upon for the materials of construction. The more important papers have been abstracted and numerous references will enable the future investigator to use these volumes as a starting point for research on any geological province or to acquaint himself with that degree of progress in the earth science which marked the nineteenth century. It must not be thought of, however, as primarily a compilation, for Suess has done this work with a breadth of view which has made all subsequent generations of geologists his debtors and has used the materials to achieve ends of his own, bringing forth conclusions which the individual workers did not perceive.

The volume opens with a description of the regions folded at the close of the Paleozoic in the old and new worlds and goes on in later chapters to consider folded tracts of later date, faulted regions, and the island arcs of the Pacific. Later parts treat of the theories of origin of these structures and of igneous activity. A chapter is devoted to the Moon and a concluding chapter to the life of the earth.

In a brief notice of a voluminous work such as this no discussion can be given of the subject matter and conclusions, as space would only permit a partial view of a few arbitrarily selected topics. It may be noted, however, regarding the mode of treatment that the work is built upon an exhaustive study of areal, structural and paleontological geology. It sums up, therefore, and uses with great power the modes of research which were especially employed in the nineteenth century. The youngest member among the family of geological sciences, physiography, has been widely applied as a mode of research only since the opening of the twentieth century and the light which it is throwing on the continental histories since the close of the Paleozoic has come too late to be incorporated into the body of this work. It is to be hoped that an English translation of this, as of the previous volumes, will soon appear in order that a wider and more intimate acquaintance of it among English readers may be acquired. J. B.

9. *Beiträge zur Flora der unteren Kreide Quedlinburgs, Teil II; Die Gattung Nathorstiana P. Richter und Cylindrites spongioides Goeppert;* by P. B. RICHTER. Pp. 11, with 62 figures and 6 plates. Leipzig, 1909 (Wilhelm Engelmann).—In this part are described in detail two new species of the new Lycopod genus *Nathorstiana* and *Cylindrites spongioides*. The latter is thought to be a strand plant, either a conifer or Pseudocycas. C. S.

10. *Cave Vertebrates of America: A Study in Degenerative Evolution;* by CARL B. EIGENMANN. Pp. ix, 241, with 72 text figs., 29 plates and frontispiece. Carnegie Institution of Washington, Publication No. 104, July 9, 1909.—Dr. Eigenmann has enjoyed unusual privileges for the study of cave life and its degenerating influence, and the results of his years of study are embodied in this handsome quarto. Some of the more striking of the author's conclusions are as follows:

"The bleached condition of animals living in the dark, an individual environmental adaptation, is transmissible and finally becomes hereditarily fixed.

"Ornamental secondary sexual characters not being found in blind fishes are, when present, probably due to visual selection.

"Individual degeneration of the eye may begin in even earlier stages of development until nearly the entire development becomes affected, that is, functional adaptations are transmissible."

The cave environment is divided into three regions: (1) Twilight just within the cave bounded by the distance to which light penetrates from without; (2) Region of fluctuating temperatures; (3) Inner cave region with absolute darkness, very slight temperature changes. The animals constituting the cave fauna are not all of one class, nor do those within one class belong to one family. They are very diverse in character and origin, but not all families of vertebrates are represented, as a certain predisposition in habit and structure is necessary.

Caves are populated by one of the four following processes: (1) By accidental carrying into caves; (2) Animals may step by step have colonized the caves, becoming adapted to the environment as successive generations gradually entered deeper and deeper recesses of the caves; (3) Animals which had elsewhere become adjusted to do without light may have gathered voluntarily in caves; (4) Animals may have developed along with the development of the caves.

The plant food of cave dwellers is from the nature of things all imported. Eyes and color tend to degenerate; but cave animals are marvelously sensitive to tactile sensations, especially to vibrations; and experiments go to prove that blind cave fishes are still sensitive to pencils of light over the entire body. In general the older caves have a more profoundly modified fauna than the newer, and cave animals tend to *converge* while epigean animals tend to *diverge*. R. S. L.

11. *Die Säugetierontogenese in ihrer Bedeutung für die Phylogenie der Wirbeltiere;* by A. A. W. HUBRECHT. Jena, 1909 (Gustav Fischer). Pp. 247, with 186 figures in the text.—In this important memoir Professor Hubrecht discusses the early ontogeny of mammals and its bearing upon the accepted phylogeny of the vertebrates. The paper sums up the later work not only of the author but of contemporary embryologists and arrives at some very interesting conclusions, several of which, however, are yet open to corroborative proof from other branches of biology.

Hubrecht regards the fœtal structures as of prime importance in the study of mammalian evolution, for the finer details of ontogeny give us a keen insight into the relationship of the various groups. The author proposes a new classification based upon this source of knowledge, which will not, however, be universally accepted. He divides the vertebrates into four super-classes: (1) Cephalochordata (Amphioxus); (2) Cyclostomata; (3) Chondrophora (Elasmobranchii); (4) Osteóphora (all higher vertebrates).

He suggests that many of the Dipnoi, Ganoids, and Teleosts may have had terrestrial ancestors just as did the Cetacea; that the mammals and Sauropsida may both trace their phylogeny back through amphibian-like Carboniferous animals and thence backward through aquatic ancestors to worm-like forms derived from the Cœlenterate stem. Based upon evidence derived from the placentation, Hubrecht concludes that Man, the Anthropoid apes and the insectivorous hedgehog are most primitive; the human ontogeny showing the most archaic characteristics of all—an interesting argument in favor of the high antiquity of Man.

R. S. L.

12. *The Occurrence of Strepsicerine Antelopes in the Tertiary of Northwestern Nevada;* by JOHN C. MERRIAM. University of California Publications, Vol. V, No. 22, pp. 319–330.—The expedition of 1909 to the Virgin Valley and Thousand Creek region of N. W. Nevada procured a wide range of mammalian forms of which a considerable per cent are new. Of these some of the most interesting are twisted-horned antelopes, known now only in Africa and throwing additional light upon past mammalian migrations. Two new genera, each with a new species, are described which are most nearly related to the strepsicerine or tragelaphine division of the antelope group, now confined to Africa, but represented by several typical twisted-horned types in Europe and Asia in later Tertiary time. R. S. L.

13. *Recherches Géologiques et Pétrographiques sur l'Oural du Nord. Le Bassin de la Haute Wichéra*; par L. DUPARC. Mem. Soc. phys. et d'hist. nat. de Genève. 4°, vol. xxxvi, fasc I, 1909, pp. 207, pls. v.—The author states that in this work he has had the coöperation, especially in the field, of Prof. F. Pearce and Mdlle. Tikanowitch. It is the third volume on this region published by the author, the two preceding volumes being devoted to other parts of the northern Urals. The geological map shows that the bottom of the basin and the course of the river is determined along belts of Devonian rocks consisting of schists and dolomites, flanked on the one side by a range of Carboniferous limestones and quartzites, and on the other by mountains of pre-Devonian metamorphic schists of various types containing quartzite belts and injected masses of diabase. The various geologic features of this region, including studies of its structure, of terrace formations, of the petrology of its rocks with a number of chemical analyses, are given in considerable detail. Attention is also paid to the iron mines in a study of them and of the probable genesis of the ores. The whole forms a useful addition to our knowledge of the geological features of a little known region. L. V. P.

14. *Laboratory Botany for the High School*; by WILLARD N. CLUTE. Pp. xiv, 177. Boston, New York, etc., 1909 (Ginn & Company).—This little laboratory manual is divided into three parts. The first deals with the structure and life processes of angiosperms; the second, with the structure and evolution of the plant kingdom; while the third describes a series of experiments in plant physiology. The distinctive feature of the book is that the student is left largely to his own resources. Under each topic a long series of questions is asked, and these are to be answered independently through the study of appropriate material. The advantage of such a method is that the knowledge thus gained will be first-hand knowledge. The disadvantage is that much of it must of necessity be fragmentary and uncorrelated. Of course a well-trained teacher would be able to counteract this disadvantage by a formal and connected presentation of the more important topics, and in the hands of such a teacher the book should prove of distinct service. A. W. E.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Norwegian Aurora Polaris Expedition 1902–1903.* Vol. I. On the Cause of Magnetic Storms and the Origin of Terrestrial Magnetism; by KR. BIRKELAND. First section. Pp. vi, 315, with 21 plates. Christiania, 1909.—The author of this work, between the years 1896–1903, carried out three expeditions to the polar regions, with the object of procuring material for the investigation of terrestrial magnetism and the aurora. The investigations are recorded in this work, the first section of volume I having the special title given above, while volume II

will treat of the aurora and some results of the meteorological observations made. The amount of material available will be obvious from the fact that in 1902 and 1903 magnetic registerings were available from twenty-five observatories, scattered over the world, including the four Norwegian stations on Iceland, Spitsbergen, Novaja Semlja, and Finmark. Certain well-marked magnetic storms in 1882-3 have also been treated from the observations in the reports of the International Polar Expedition. The author in 1896 advanced the theory that magnetic disturbances on the earth, as well as the aurora borealis, are due to corpuscular rays emitted by the sun; and the observations recorded have been treated with a view to show their relation to this theory. He says: "The magnetic storms, for instance, have been studied in such a manner, that on the one hand we have formed from our observation-material a field of force which gives as complete a representation as possible of the perturbing forces existing on the earth at the times under consideration. On the other hand, by experimental investigations with a little magnetic terrella in a large discharge-tube, and by mathematical analysis, we have endeavoured to prove that a current of electric corpuscles from the sun would give rise to precipitation upon the earth, the magnetic effect of which agrees well with the magnetic field of force that was found by the observations on the earth."

He adds: "The disintegration theory, which has proved of the greatest value in the explanation of the radio-active phenomena, may possibly also afford sufficient explanation as to the origin of the sun's heat. The energy of the corpuscular precipitation that takes place in the polar regions during magnetic storms seems, indeed, to indicate a disintegration process in the sun of such magnitude, that it may possibly clear up this most important question in solar physics."

He believes that future results in this line will serve to solve the questions as to the origin of terrestrial magnetism and that of the sun's heat. Professor Störmer has carried on the mathematical investigations in connection with the author's theory, which are intended to make clear the movement of electric corpuscles from sun to earth. These will be published in a special part of the present work.

The author considers it to be beyond doubt that the powerful magnetic storms in the northern regions are due to the action of electric currents above the earth near the auroral zone. The attempt has been made in the case of some of the storms to calculate the strength of horizontal currents that would cause them, supposing that they acted magnetically as galvanic currents. In the case of the greater storms, current strengths of from 500,000 to 1,000,000 amperes or even more have been obtained. He has calculated also that according as to whether the currents are due to cathode or to β-rays, the energy for 1,000,000 amperes would be $19·6 \times 10^6$ or $5·35 \times 10^6$ horse-power. Further considerations lead to an estimate of 10^{13} horse-power for the energy of the rays that would come in contact with the earth if the latter was non-magnetic.

2. *Carnegie Institution of Washington.*—In connection with the dedication of the administration building of the Carnegie Institution at Washington, Dec. 13, 1909, a pamphlet has been issued describing the plan and scope of the Institution, and showing in brief form what it has grown to be in the past eight years. There are ten departments enumerated, most of which have their own permanent homes where active research is being carried on ; these are illustrated by numerous views in this report.

The Eighth Year Book of the Institution (pp. vii, 259, with 16 plates), which has just appeared, gives a detailed account of its work during the year 1909. On the financial side it is interesting to note that about $700,000 of income were available, of which the sum of $467,500 was expended for the now well established larger projects, $50,000 for minor grants to individuals, $30,600 for research assistants and $104,600 for publication and administration. The entire amount expended by the Institution up to 1910 reaches the imposing total of $4,129,000.

The work of the Institution has expanded in a remarkable manner, particularly along the lines determined by the various special departments of research to which the resources are chiefly devoted. These include, as enumerated in former notices, the Solar Observatory in California ; the Geophysical Laboratory in Washington (the important results from which are contained in this Journal); the Marine Biological Laboratory at Tortugas, Florida, and that of Experimental Evolution at Cold Spring, N.Y.; the Desert Botanical Laboratory at Tucson, Arizona, and others. The non-magnetic yacht Carnegie started on her first trip in August last and at this date has just returned from a highly successful voyage of 8,000 miles. An interesting digest of the results accomplished in these and the other lines of research is given in the Year Book ; as a whole it gives a good idea of the efficiency of the entire organization under the charge of Dr. Woodward, and the vast amount of good work which is being accomplished.

As noted above, the administration of the Institution has now a permanent home in a handsome building at the corner of Sixteenth and P streets in Washington, dedicated in December last. The work of publication has gone on steadily through the year, nineteen volumes, aggregating about 5,000 pages, having been issued (see vol. xxvii, 347, xxviii, 564). The total number of publications is now 141, with some 35,000 printed pages.

3. *The Carnegie Foundation for the Advancement of Teaching. Fourth Annual Report of the President*, HENRY SMITH PRICHETT, *and the Treasurer*, THOMAS MORRISON CARNEGIE. Pp. 201; 576 Fifth Avenue, New York City.—At the end of September last the total funds of the Carnegie Foundation amounted to $11,108,000. The income for the year was $544,355, of which $343,870 was paid out for retiring allowances and about

$53,600 for expenses of administration, publication, etc. An unexpended balance of $147,000 remained, which is included in total amount of the fund as stated above. During the year 115 pensions aggregating $177,000 were granted, bringing the number of pensions now being paid up to 318, involving a cost of $466,000; this statement alone shows how widely the benefits of this great contribution to the cause of the higher education are being distributed. There are now 67 institutions in the accepted list, including five state institutions, one of these at Toronto, Canada.

An important change has been made the past year in the working of the system, the service pension, which allowed an individual to retire at any age after twenty-five years of professional service, having been withdrawn except in the case of teachers who from disability are unable to continue active work. On the other hand, the age pension, which as previously allows retirement at an age of sixty-five years, is extended to all who have served twenty-five years, including their work as instructors. The reasons which have led to these changes are clearly stated by the President. A variety of other problems are also discussed by him: these are in part administrative, dealing with college finances and financial reports, advertising, the function of the trustee, and other related points. Other matters treated of are educational and have to do with the standards of entrance examinations, and of college and university instruction in general. The Foundation aspires to be a powerful force in raising and unifying college requirements and standards; in this direction it can accomplish great good, but constructive criticism from without, in the case of an established institution, involves many delicate questions which require careful handling that good results may be assured.

4. *Relief Maps.*—The geological department of the University of Wisconsin has prepared a geological relief map, or model, of the state of Illinois, copies of which may be purchased from the Board of Regents at Madison for $100. The map framed is 6 feet 7 inches × 3 feet 9 inches, and is on a horizontal scale of five miles to one inch and a vertical scale of 1320 feet to one inch. A model of the Malaspina glacier, Alaska, including the adjacent region near Mt. St. Elias and Yakutat Bay, may also be obtained for $125. It is about 7 feet × 4⅝ feet, and is on a scale (horizontal and vertical) of 1 : 80,000 or one inch to one and one-quarter mile.

5. *Report of the Librarian of Congress and Report of the Superintendent of the Library Building and Grounds* for the fiscal year ending June 30, 1909. Pp. 220, with 6 illustrations. Washington, 1909.—The Library of Congress is so universally recognized now as the standard of work of that kind in the country that the report of Mr. Putnam has great interest for those especially concerned. It may be noted that the appropriation for 1910 amounts to $855,000 as against an expenditure of $685,560 in 1909. The Library on June 30th, 1909, contained 1,703,000

books, a gain of nearly 168,000 for the year. The most important accession of the year was a gift from the Chinese Government of a set of the great Chinese Encyclopædia, comprising over 5,000 volumes; this was brought to Washington by a special ambassador. Another important gift is that of one hundred printed volumes from the library of George Bancroft presented by Mrs. J. C. Bancroft Davis. The Library has also issued the following:

Want List of Publications, 1909, pp. 30.

Publications issued since 1897. Pp. 48. January, 1910.

Select List of References in Sugar, chiefly in its economic aspects; compiled under the direction of HERMANN H. B. MEYER. Pp. 238.

4. *Harvard College Observatory:* EDWARD C. PICKERING, Director.—Recent publications are noted in the following list (continued from vol. xxviii, p. 565).

ANNALS. Vol. LII, Part II. A Discussion of the Eclipses of Jupiter's Satellites, 1903–1893; by RALPH ALLEN SAMPSON. Pp. 153–343, with 4 plates.

Vol. LV, Part II. Maxima and Minima of Variable Stars of Long Period; by ANNIE J. CANNON, under the direction of EDWARD C. PICKERING. Pp. 99–291.

Vol. LIX, No. V. Photographic Magnitudes of 76 Stars; by EDWARD S. KING. Pp. 128–155.

Vol. LXIX. Part I. Photometric Observations made with the Fifteen-inch East Equatorial during the Years 1892 to 1902; by OLIVER C. WENDELL. Pp. iii, 97.

Vol. LXX. Durchmusterung Zones observed with the Twelve-inch Meridian Photometer; by EDWARD C. PICKERING. Pp. vi, 235.

CIRCULARS. No. 149. Group of Red Stars in the Constellation Sagittarius. Pp. 3.

No. 150. A Standard Scale of Photographic Magnitudes. Pp. 7.

No. 151. 20 New Variable Stars in Harvard Map, No. 49. Pp. 4.

No. 152. New Variable Stars in Harvard Map, Nos. 2, 5, 32, 44, and 53. Pp. 3.

OBITUARY.

M. SERGE NIKITIN, geologist-in-chief of Comité Géologique of Russia, died on the 18th of November, 1909.

Dr. SHELFORD BIDWELL, the English physicist, died on December 18 at the age of seventy-one years.

New Circulars.

84: Eighth Mineral List: A descriptive list of new arrivals, rare and showy minerals.

85: Minerals for Sale by Weight: Price list of minerals for blowpipe and laboratory work.

86: Minerals and Rocks for Working Collections: List of common minerals and rocks for study specimens; prices from 1½ cents up.

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Prof. W. G. Farlow.

L. XXIX. APRIL, 1910.

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VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

No. 172—APRIL, 1910.

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Art. XXII.—*Studies on the General Circulation of the Earth's Atmosphere;* by Frank H. Bigelow.

A Discussion of the Departures and the Residuals of the Temperature and Precipitation in Climatology.

Meteorological and climatological observatories, at numerous stations in all parts of the world, are turning out an enormous mass of raw material every year, which is of only moderate value unless it can be intelligently and thoroughly discussed. This material consists of daily observations which, when collected together in tables, produce the daily, monthly and annual means, respectively, by the usual processes of summation for the several time-terms. When these time-terms or periods are repeated many times, a normal mean can be computed as a reference value. The variations of each time-term on the normal may be called its *departure;* the variation of a time-term on its *consecutive mean* may be called its *residual.* To illustrate these terms, take the following examples derived from Bulletin S, U. S. Weather Bureau, as given in table 1, 1909. The annual means from 1873 to 1905 for five stations are called t_1, t_2, t_3, t_4, t_5, and this notation can be extended for n stations to t_n. When the original observations are reduced to a *strictly homogeneous* series by eliminating the errors of observing and computing, the mean of a long record, as of thirty-three years, is the *normal*, t_0. The differences t_1-t_0, t_2-t_0, . . . t_r-t_0, for the several years, r in number, give the *departures*, v_1 having r values for the first station, v_2 having r values for the second station, and v_n having r values for the nth station. There are rn departures for n stations and r time-terms. Since it is evident that in restricted areas, as the Lake Region of the United States, the variations

Figs. 1-3.

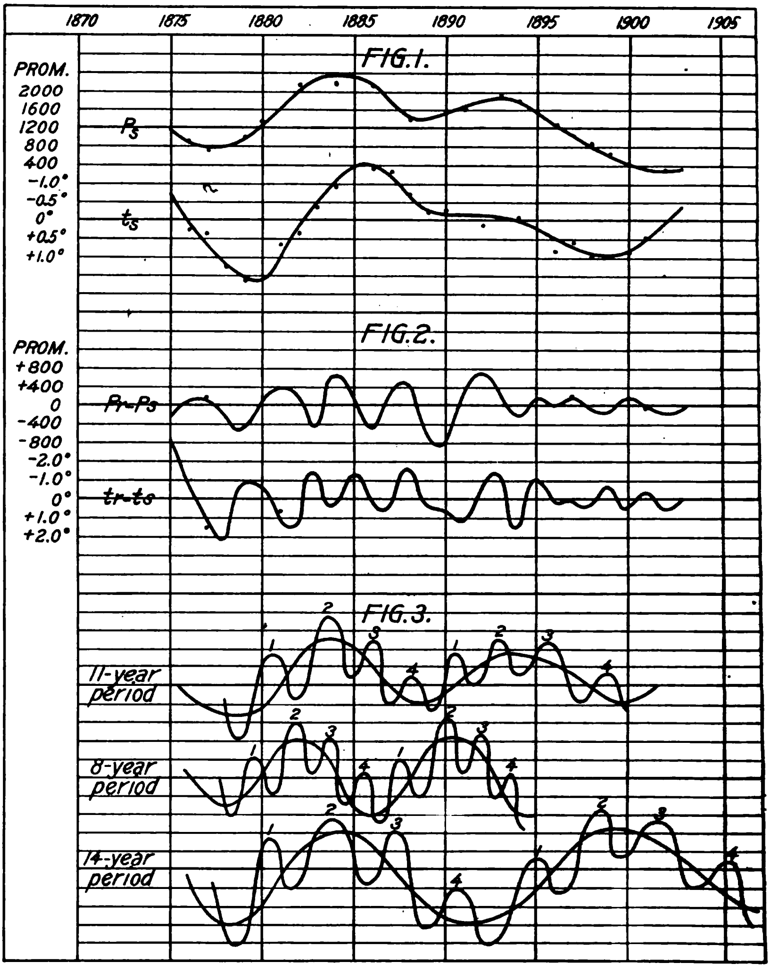


Fig. 1. Long period of prominences and temperatures.
Fig. 2. Short period for prominences and temperatures.
Fig. 3. Summation of variable periods in a single definite period.

in the temperature system, month by month, year by year, are similar, it is proper to concentrate the departures by taking the mean, τ, for several stations, 5 in this case, or n in general. The mean departures, τ_r, for r years, make good material for the discussion of problems concerned with the general and

TABLE I.—ILLUSTRATIONS OF TIME-TERMS, DEPARTURES, MEAN DEPARTURE, CONSECUTIVE DEPARTURE AND RESIDUALS.

Stations $n=5$	Marquette, Mich.	Milwaukee, Wis.	Chicago, Ill.	Alpena, Mich.	Detroit, Mich.	Departures for the term-times $r=33$ in number					Mean departure	Consecutive means Long period	Prominences Long period	Temperature Short period	Prominences Short period
Ye'r	t_1	t_2	t_3	t_4	t_5	v_1	v_2	v_3	v_4	v_5	τ_r	τ_s	P_s	$\tau_r-\tau_s$	P_r-P_s
1873	38·5	44·1	47·4	39·8	46·5	−2·0	−1·2	−1·1	−1·9	−1·7	−1·6	----	----	----	----
74	40·5	46·1	50·6	41·4	48·6	0·0	+0·8	+2·1	−0·3	+0·4	+0·6	----	----		----
75	36·4	40·9	45·6	37·6	44·4	−4·1	−4·4	−2·9	−4·1	−3·8	−3·9	−0·7	1188	−3·2	−332
76	40·1	44·1	49·2	41·0	47·5	−0·4	−1·2	+0·7	−0·7	−0·7	−0·5	+0·3	865	−0·8	+ 11
77	43·8	46·1	50·5	43·5	49·3	+3·3	+0.8	+2·0	+1·8	+1·1	+1·8	+0·3	695	+1·5	+ 47
78	45·8	48·7	51·7	45·2	49·9	+5·3	+3·4	+3·2	+3·5	+1·7	+3·4	+1·3	791	+2·1	−353
79	42·0	46·4	50·1	41·5	48·2	+1·5	+1·1	+1·6	−0·2	0·0	+0·8	+1·7	1015	−0·9	−454
1880	41·3	46·9	50·8	42·4	48·9	+0·8	+1·6	+2·3	+0·7	+0·7	+1·2	+1·7	1332	−0·5	+ 6
81	40·3	46·6	49·6	42·2	51·5	−0·2	+1·3	+1·1	+0·5	+3·3	+1·2	+0·6	1604	+0·6	+394
82	41·6	47·4	49·8	42·8	51·5	+1·1	+2·1	+1·3	+1·1	+3·3	+1·8	+0·4	2063	+1·4	+264
83	37·5	43·6	46·5	38·9	48·0	−3·0	−1·7	−2·0	−2·8	−0·2	−1·9	−0·4	2252	−1·5	−456
84	38·4	44·1	48·4	40·6	50·0	−2·1	−1·2	−0·1	−1·1	+1·8	−0·5	−0·9	2170	+0·4	+686
85	37·5	41·6	46·7	38·0	47·2	−2·9	−3·7	−1·8	−3·7	−1·0	−2·6	−1·4	2280	−1·2	+ 4
86	39·9	40·9	49·2	40·7	49·2	−0·6	−4·4	+0·7	−1·0	+1·0	−1·3	−1·4	2098	+0·1	−513
87	39·1	44·8	47·9	40·8	48·7	−1·4	−0·5	−0·6	−0·9	+0·5	−0·6	−1·3	1671	+0·7	+206
88	37·4	43·2	46·8	39·8	46·0	−3·1	−2·1	−1·7	−1·9	−2·2	−2·2	−0·7	1352	−1·5	+585
89	41·0	45·9	48·4	42·3	47·8	+0·5	+0·6	−0·1	+0·6	−0·4	+0·2	−0·2	1402	+0·4	−678
1890	40·7	46·2	48·8	42·2	48·3	+0·2	+0·9	+0·3	+0·5	+0·1	+0·4	−0·2	1521	+0·6	−836
91	42·1	46·6	48·4	43·2	48·4	+1·6	+1·3	−0·1	+1·5	+0·2	+1·2	−0·1	1592	+1·3	+244
92	40·5	44·4	46·8	41·7	47·4	0·0	−0·9	−1·7	0·0	−0·8	−0·7	+0·2	1740	−0·9	+732
93	38·9	43·9	46·5	41·0	46·8	−1·6	−1·4	−2·0	−0·7	−1·4	−1·4	0·0	1936	−1·4	+310
94	42·4	47·4	49·8	43·6	49·2	+1·9	+2·1	+1·3	+1·9	+1·0	+1·6	0·0	1806	+1·6	−339
95	40·3	44·8	47·5	41·4	46·7	−0·2	−0·5	−1·0	−0·3	−1·5	−0·7	+0·3	1534	−1·0	+106
96	41·6	46·8	49·8	42·9	48·4	+1·1	+1·5	+1·3	+1·2	+0·2	+1·1	+0·9	1230	+0·2	− 19
97	41·2	46·6	48·8	43·1	48·1	+0·7	+1·3	+0·3	+1·4	−0·1	+0·7	+0·6	1037	+0·1	+ 76
98	42·2	47·0	49·1	44·1	49·6	+1·7	+1·7	+0·6	+2·4	+1·4	+1·6	+1·0	817	+0·6	− 96
99	40·2	46·3	48·8	42·0	48·3	−0·3	+1·0	+0·3	+0·3	+0·1	+0·3	+0·9	604	−0·6	−106
1900	42·6	47·2	48·9	43·8	49·1	+1·2	+1·9	+0·4	+2·1	+0·9	+1·5	+0·8	398	+0·7	+145
01	41·4	46·0	47·8	42·4	47·5	+0·9	+0·7	−0·7	+0·7	−0·7	+0·2	+0·5	295	−0·3	−150
02	42·2	46·3	48·6	42·8	48·2	+1·7	+1·0	+0·1	+1·1	0·0	+0·8	+0·1	305	+0·7	−222
03	41·0	45·2	47·4	42·4	47·6	+0·5	−0·1	−1·1	+0·7	−0·6	−0 1	−0·3	300	+0·2	− 96
04	38·6	44·0	46·2	39·6	45·6	−1·9	−1·3	−2·3	−2·1	−2·6	−2·0	----	----	----	----
05	40·0	45·3	48·0	41·6	47·5	−0·5	0·0	−0·5	−0·1	−0·7	−0·4	----	----	----	----
t_0	40·5	45·3	48·5	41·7	48·2										

	Residuals	u_1	u_2	u_3	u_4	u_5
1873		−0·4	+0·4	+0·5	−0·3	−0·1
74	$u_1=v_1-\tau$	−0·6	+0·2	+1·5	−0·9	−0·2
75	$u_2=v_2-\tau$	−0·2	−0·5	+1·0	−0·2	+0·1
76	$u_3=v_3-\tau$	+0·1	−0·5	+1·2	−0·2	−0·2
77	$u_4=v_4-\tau$	+1·5	−1·0	+0·2	0·0	−0·7
78	$u_5=v_5-\tau$	+1·9	0·0	−0·2	+0·1	−1·7
79		+0·7	+0·3	+0·8	−1·0	−0·8
1880		−0·4	+0·4	+1·1	−0·5	−0·5
81		−1·4	+0·1	−0·1	−0·7	+2·1
82		−0·7	+0·3	−0·5	−0·7	+1·5

cosmical causes, such as the movement of the sun in declination, from 23° north latitude to 23° south latitude, due to the annual motion of the earth about the sun, the rotation of the sun on its axis, the aperiodic fluctuations of the solar radiation due to its thermodynamic internal actions, which affect the temperatures of the earth in small regions or as a whole. These mean departures, τ_r, usually consist of long and short fluctuations, and it is necessary to separate them in preliminary studies, in order to obtain some idea of the kind of action underlying the variations, with the purpose of finding out the laws representing the physical processes involved. The most convenient way is to take *consecutive means* for a selected number, τ_s, of the available r time-terms. In the example the consecutive years are 5 in number, and the 5-year means τ_s derived from τ . . . . . τ_5 in succession are placed in the next column, that for 1873–1877 against 1875, that for 1874–1878 against 1876, the last being 1900–1905 against 1903. The τ_s consecutive departures represent the *long period term*, which is found in the rapidly changing system of departures v_{rn}. The *short-period term* is found by subtracting each τ_s from τ_r in succession, so that the *residuals*, $\tau_r - \tau_s$, are short period variations in the system of departures. Examples of the use of this method can be found in the following papers: Bulletin R, The Daily Normal Temperature and Precipitation of the United States; Abstract of data, No. 3, The Annual Precipitation of the United States; this Journal, vol. xxv, p. 413, May 1908, The Relation between the Meteorological Elements of the United States and Solar Radiation. In the last paper the data of the solar prominence frequency numbers and the European horizontal magnetic force are treated in the same way, and the data of the solar prominences here used are extracted from it. The long-period consecutive means P_s, for 5-year intervals, and the short-period residuals, $P_r - P_s$, are placed in Table 1; they are plotted together with the corresponding temperature variations in fig. 1. An inspection of these diagrams brings out clearly several features of the problems of *departures* and *residuals*, which must be carefully considered in discussing the physical causes that produce them. It is apparent that the long-period curves have a similar synchronism, but that the temperatures *seem to lag for about two years* behind the prominences during the interval 1877 to 1888, while the lag has apparently disappeared after 1888. In the short-period the same lag occurs in the first half of the run, the crests being displaced in the temperatures about two years to the right, while in the second part of the curve the crests synchronize or become minor and irregular together. Both sets of curves are inverted so that an *increase in the solar prominence frequency* is followed by a *decrease in the annual temperatures* of the Lake Regions of the United States.

It is not our purpose to discuss these problems here other than as illustrating certain principles in the discussion of departures and residuals in solar and meteorological data derived from observations. Similar data, as stated, are being collected in every branch of physics pertaining to the atmospheres of the sun and the earth. In stellar and planetary astronomy the problems of variations and departures, called perturbations, are comparatively easy, because the effects of the laws of gravitation are studied in rigid masses that can be reduced to ideal points. In astrophysics and meteorology these problems become enormously difficult, because the masses are gases flowing in complex paths that cannot be traced directly, as one follows a comet or a planet in the heavens, but only indirectly in the accumulated effects of a general circulation, and its local disturbances, that is in the barometric pressures, the temperatures, the densities, and the velocities of the atmosphere, at the numerous meteorological stations, these being located only in the lowest stratum of the moving fluid. The problem is so exceedingly difficult in itself that we may fairly be permitted to employ such means of discussion as are obviously suitable in order to avoid an inevitable failure in reaching a valuable result. The problems of solar and terrestrial synchronism can be discussed by two general methods, (1) a strictly rigid mathematical analysis, and (2) a statistical method combined with an interpretation guided by graphic traces. The former is preferred by some as applying definite principles, and allowing no chance for accommodation by a biassed judgment; the latter is preferred by many as the only method for a first approximation to a clear understanding of relations too complicated to be unravelled by any mathematics now in existence. Some criticise the former method as allowing no room for the practical judgment, and the latter method is criticised by others as allowing too much room for the judgment, especially on the part of those who seek a special result. The truth seems to be that the former method is allowable for the adjustment of the constants and terms of an equation *wherein the physical processes are already approximately understood.* The latter method is necessary and allowable in those preliminary researches which seek to discover what the law in question is, rather than in the refinement of it. The first method always leads to zero-results in dealing with solar and terrestrial phenomena. The latter offers some hope of success in the present state of the development of this branch of science. We mean to include under the former method of rigid analysis, (1) the usual application of the theory of least squares for the detection of an unknown period, by the criterion of the sum of the squares of the departures being a minimum; (2) Professor Schuster's Harmonic Analysis and Periodogram for the detection of hidden periodicities, Terr. Mag. 1898; (3) the Fourier series in various forms of the harmonic analysis; (4) Professor Newcomb's criterion for fluctuations without any discernible period, Am. Phil. Soc., vol. xxi, part v, 1908.

Periodic and aperiodic synchronism.

There is one general principle underlying each of these methods of analysis, namely, that they seek a *definite period*, and assume as the premise of argument that synchronism between solar and terrestrial variations depends upon the existence and proof of such a period. It has, however, not been established that the cycle of the solar thermodynamic processes is periodic, in anything like the same sense that the annual orbital motion of the earth about the sun produces one true period in the processes within the earth's atmosphere, while the rotation of the earth on its axis produces another true periodic cycle of variations. On the contrary, the observed solar processes are so irregular as to be distinctly aperiodic. The so-called 11-year period varies between 8 years and 14 years in length in an irregular succession; the synodic rotation of the sun on its axis varies in latitude and altitude above the photosphere, from 26·7 days at the equator to 31·0 days near the poles for the level of the photosphere, but from 26·0 days at the equator to something like 29 days for the upper levels of the chromosphere. There are numerous irregularities noted in the irruption of the prominences in different longitudes so that they appear earlier in the middle latitudes of the sun than in the equatorial and the polar zones. Furthermore, it is found that in the analysis of the sun spot numbers, the prominence frequencies, and the magnetic field intensities, there is usually superposed upon the long period, ranging from 8 to 14 years, four minor crests, though only three of them are fully developed in some periods. If, for example, we assume a long period of variable length, having three or four minor variations within each of them, and attempt to sum them together on any assumed definite period, the result will be similar to that displayed in fig. 3. If the 11-year period with four crests be summed with an 8-year period and a 14-year period, it is evident that the summation will destroy all evidences of periodicity and synchronism in the minor fluctuations. The long periods may survive with a feeble amplitude, while the short periods will certainly vanish. It is a misnomer to speak of these irregular oscillations as periods, and it is a non sequitur of analysis to assume that synchronism depends upon periodicity. If the irregularities in the variations of the solar and the terrestrial phenomena match each other in the time-sequences, this is a better proof of synchronism in physical causes and effects than could be obtained by employing a definite period having wide amplitudes of oscillation.

Inversion effects.

Besides the impropriety of forcing the observed departures of different phenomena into mean periods which do not exist in nature, there is a failure to recognize the fact that the same external or general cause, as an increase in the solar radiation energy, may produce inverted effects within the earth's atmosphere when different localities are compared together. Since the total weight of the earth's atmosphere remains fixed, it is obvious that the *pressures* of the atmosphere can be distributed in diverse manners only by balancing an excess in one region by a defect in another region. It has been found that the pressures of the atmosphere of the earth as a whole vary in such a manner that the years of annual excess in the eastern hemisphere are compensated by simultaneous deficiencies in the western hemisphere, the variations following the sequence of the solar prominences. Since the sum of the moments of inertia for the whole earth's atmosphere must be equal, in order to maintain the period of the earth's rotation on its axis a constant, it follows that the *circulation* of the atmosphere adjusts itself automatically under the action of the force of gravitation to certain velocities appropriate to the latitude away from the equator, and the height above the earth's surface. This complex process is only partially understood as yet, but it is evident that along with the readjustment of the circulation there is a redistribution of the terrestrial temperatures in latitude and in longitude. Thus, it has been found that the year of excess of temperature in the tropical zone is accompanied by a defect of temperature in the temperate zones, this being due to the return-cold or polar currents bringing down air from the higher levels to the surface in temperate zones, to compensate for the increase of the upward circulation in the Tropics as caused by the increase in the solar radiation. This general principle has many exceptions in the temperate zone, due to the relative action of the continents and the oceans upon the general circulation in the surface levels where the observations are generally made. Again, it is not possible to treat a continent, or even a portion of a continent, as a unit. Thus, there is usually a temperature oscillation between the Pacific States and the Central and the Eastern States in North America, one being high while the other is low. Sometimes the interior stations of the United States show an excess of temperature, while all the states bordering on the Atlantic Ocean, the Gulf of Mexico and the Pacific Ocean have a simultaneous defect. The complications of the circulation are excessive and difficult to classify in a simple system, but it is important to emphasize the fact that stations from all parts of the world cannot be massed together for short-period variations, and even for long-period oscillations a discriminating knowledge and judgment is demanded. The selection of stations for any least square or harmonic analysis should have as much regard for the fact of inversion-effects, proceeding from the same external general cause, as for the other fact that periodicity is not necessary for synchronism in physical processes.

Homogeneous direct observations.

The means, departures, consecutive means, and the residuals, depend upon *original observations which must be homogeneous* to produce valid variations of any sort. In the temperatures, the observations are made at a few selected hours; in the precipitation they are made occasionally, at the end of the irregular rain and snow intervals; in the solar prominences they are made from a few stations as sights of the sun are permitted by local cloudiness; and similarly with other phenomena. In the United States the daily temperatures depend upon observations made at 7 A. M., 3 P. M., 11 P. M., Washington meridian time, 1871–88; at 8 A. M., 8 P. M., 75th meridian time, or maximum and minimum temperatures since July, 1888. Previous to the publication of Bulletin S, 1909, there was no series of homogeneous temperatures in the United States available for discussion. The hours of observation differ widely in other countries, and in general the entire subject of temperature variations for the world is very chaotic and unsatisfactory. The practical difficulty of securing 24 hourly observations every day, except by self-registering instruments, is so great that different combinations of selected hours have been used as substitutes, to the great detriment of scientific meteorology. Since the selected hours of observation are on Washington or 75th meridian mean time, it follows that the local hours of observation change by the difference of longitude between the standard meridian and the local meridian, so that 8 A. M., 8 P. M. becomes 7 A. M., 7 P. M. on the 90th meridian, 6 A. M., 6 P. M. on the 105th meridian, 5 A. M., 5 P. M. on the 120th meridian. If the mean of 8 A. M. and 8 P. M. on the 75th meridian gives the same mean as the mean of 24 hourly observations, it will not do so on other meridians at some distance from it, because the temperatures change with the local hours. The mean of the maximum and the minimum temperatures, taken with the standard thermometers, is the best substitute for 24 hourly readings, considering all the irregularities produced by local conditions, though a correction is required for accuracy. It is obvious that these selected hourly readings having been used to compute the daily, monthly and annual means, from which the normals, departures, and residuals are derived, introduce systematic errors in the variations, which render them unfit for discussion by any graphic method or harmonic analysis. If the published reports in meteorological libraries are used without any reconstruction such as that indicated, it is evident that conclusions derived from them cannot carry much weight in any problem of solar and terrestrial synchronism.

Grouping of Stations into districts and size of means.

A preliminary examination of the pressure and temperature departures for the whole earth, 1873–1901, as published in the Monthly Weather Review, November 1903, indicates the following conclusions: (1) inversion of pressure variations between the eastern and western hemispheres; (2) inversion of temperature variations between the tropics and the polar temperate zones; (3) very small survival of the long, or 11-year, period, for the entire earth; (4) comparatively large departures for the short, or 3-year, period; (5) the inversion of temperature from the tropics to the poles producing a vanishing or irregular variation along the high pressure belt near latitude 35°; (6) an increase of amplitude in the direct temperature type towards the equator, and an increase in the amplitude of the inverse type towards the pole from latitude 35°; (7) a tendency to invert between the ocean and continent; (8) that the 11-year period amplitude does not diminish from the equator to the pole by the function of the cosine of the latitude; (9) that it is not proper to combine tropical and temperate zone stations in the same summation without regard to inversion; (10) that it is not proper to combine several periods of unequal length in one summation without reducing the phases for the short period to an assumed standard period, as 11-years.

To illustrate a few of these points, take the stations in the United States, Washington, Key West, Galveston, St. Louis, Salt Lake City, Phœnix, San Diego, and sum the departures as follows in four groups, in Table 2:

Eastern Districts, Wash., K. W., Gal., S. L. and take mean τ_1
Western Districts, Salt Lake, Ph., S. D. " " " τ_2
Inland or Northern, Wash., S. L., S. L. C., Ph. " " " τ_3
Coast or Southern, K. W., Gal., S. D. " " " τ_4

If now we combine τ_1 and τ_2 in a general sum, taking the sum of the positive values of τ_1, and setting against τ_2 the algebraic sum as it comes, in order to see whether there is inversion or not within the United States, we find the following results:

When $\tau_1 = + 10{\cdot}7,\ \tau_2 = - 4{\cdot}2$
$\tau_1 = - 10{\cdot}1,\ \tau_2 = + 1{\cdot}9$

showing that there is a tendency to inversion between eastern and western districts. Similarly,

when $\tau_3 = + 11{\cdot}0,\ \tau_4 = 0{\cdot}0$
$\tau_3 = - 10{\cdot}4,\ \tau_4 = - 0{\cdot}9$

showing that when the inland or northern districts vary the tendency is for the coast and southern districts to fluctuate accidentally. The smallest variations in the United States are on the Southern Rocky Mountain plateau, and the largest in the Lake Region. Similar studies should be made of residuals before attempting to combine them, because the same external and general cause produces inverted effects through the action of the complex circulation of the atmosphere, as will be explained in other papers.

The size of the annual departures demands a statement as regards their value in practical meteorology. On the face of it, the annual variations on the normals are small, and they show that there is no secular progressive change in the conditions of the climate. An examination of the daily and monthly means from which the annual means are divided shows that the years divide into two classes, (1) those of *wide* oscillations and those of *narrow* oscillations. When the years of wide swing occur it implies that the cold polar currents and the warm tropical currents which meet in the United States are each respectively more pronounced, colder and warmer in succession, than in the quiet years. This intensification of warm and cold currents is due to an increase in external solar radiation, which produces a stronger general and a more irregular local circulation. Now the mean of these wide oscillations of the several months in a year, amounting in the winter in the Lake Region to as much as plus 18° F. to minus 18° F., will be about the

TABLE II.—GROUPING OF THE DEPARTURES IN DIFFERENT DISTRICTS.

Year	Wash.	K. W.	Gal.	S. L.	S. L. C.	Ph.	S. D.	τ_1	τ_2	τ_3	τ_4
1873	+0·4	+0·3	−0·7	−1·6	....	....	−0·1	−0·4	−0·1	−0·6	−0·2
74	+1·6	+1·1	+0·5	+1·1	..	....	−1·2	+1·1	−1·2	+1·4	+0·1
75	−2·2	+1·4	−0·2	−2·4	+0·9	....	+0·9	−0·9	+0·9	−1·2	+0·7
76	−0·1	+0·3	0·0	−0·2	−0·4	....	+0·2	0·0	−0·1	−0·2	+0·2
77	+1·1	+0·3	−1·0	+0·9	−0·1	+0·5	+1·8	+0·3	+0·6	+0·6	+0·2
78	+1·6	+0·4	0·0	+1·8	+0·4	−0·5	−0·2	+1·0	−0·1	+0·8	+0·1
79	+0·7	+0·4	+0·8	+0·1	+1·4	+1·2	−0·7	+0·5	+0·6	+0·9	+0·2
1880	+1·3	+2·0	−0·2	−0·5	−3·0	−0·3	−2·3	+0·7	−1·9	−0·6	−0·2
81	+1·5	+1·4	+0·1	+0·4	+0·3	−2·0	−0·3	+1·1	−0·7	0·0	+0·4
82	+0·4	+1·5	+1·5	0·0	−2·3	+0·3	−0·9	+1·1	−1·0	−0·4	+0·7
83	−0·4	+1·7	+0·6	−2·0	−0·8	−0·6	+0·4	0·0	−0·3	−1·0	+0·9
84	+0·6	+0·9	+0·3	−0·3	−0·7	−2·3	−0·1	+0·4	−1·0	−0·7	+0·4
85	−1·5	−0·2	−0·2	−1·0	+0·8	−0·4	+1·4	−0·7	+0·6	+0·5	+0·3
86	−1·0	−0·8	−1·9	−2·5	0·0	−0·1	−0·3	−1·6	−0·1	−0·9	−1·0
87	+0·4	−0·6	+0·4	+1·9	+1·2	....	−0·2	+0·5	+0·5	+0·9	−0·1
88	−1·2	+0·3	−0·1	−1·6	+1·8	....	+0·8	+0·7	+1·3	−0·3	+0·3
89	0·0	+0·2	−0·2	−0·1	+1·7	....	+1·2	0·0	+1·5	+0·4	+0·4
1890	+1·1	+0·2	+1·8	+1·0	+0·6	....	+1·1	+1·0	+0·9	+0·9	+1·0
91	+0·1	−0·4	+0·5	+0·1	−0·6	....	+0·8	+0·1	+0·1	−0·1	+0·3
92	−0·8	−1·0	−0·3	−0·8	−0·2	....	−0·4	−0·7	−0·3	−0·6	−0·6
93	−1·2	0·0	+0·7	−0·6	−1·1	....	−0·2	−0·3	−0·7	−1·0	+0·2
94	+1·2	−0·3	+0·4	+1·3	−1·1	....	−2·9	+0·7	−2·0	+0·5	−0·9
95	−0·9	−0·8	−1·8	−1·0	−1·3	...	−0·6	−1·1	−1·0	−1·1	−1·1
96	+0·4	−0·3	+0·7	+1·6	+0·1	+0·8	+0·8	+0·6	+0·4	+0·7	+0·4
97	0·0	+0·3	+0·6	+1·1	−0·5	−0·8	−0·3	+0·5	−0·5	−0·1	+0·2
98	+1·1	−0·6	−0·4	+0·9	−1·5	+0·5	−0·6	+0·3	−0·5	+0·3	−0·5
99	−0·5	−0·2	−0·6	+0·4	−0·6	+0·3	−1·0	−0·2	−0·4	−0·1	−0·6
1900	+1·6	−1·0	+0·4	+1·9	+2·1	+1·3	+0·9	+0·7	+1·4	+1·7	+0·1
01	−0·8	−2·1	−0·3	+1·2	+1·6	+1·1	+0·1	−0·5	+0·9	+0·8	−0·8
02	+0·2	−0·6	+0·2	+0·6	+0·8	+0·7	−1·0	+0·1	+0·2	+0·6	−0·5
03	−0·6	−0·8	−1·5	−0·2	−1·2	+0·2	−0·1	−0·8	−0·4	−0·5	−0·8
04	−2·6	−1·1	0·0	−1·8	+0·3	+1·2	+1·2	−1·4	+0.9	−0·7	0·0
05	−0·9	−0·6	−0·7	−0·9	+0·2	+0·4	+0·4	−0·8	+0·3	−0·3	−0·3
Combinations of Stations								+10·7 −10·1	−4·2 +1·9	+11·0 −10·4	0·0 −0·9

τ_1	Wash., K. W., Gal., S. L.	Eastern Districts
τ_2	S. L. C., Ph., S. D.	Western Districts
τ_3	Wash., S. L., S. L. C., Ph.	Inland Districts
τ_4	K. W., Gal., S. D.	Coast Districts

same as when the monthly oscillations are only 6° F. or 5° F., when the twelve months are summed together. In so long an interval as 365 days, the oscillations due to the passage of cyclones and anticyclones, whether they are strong or weak in type, nearly balanced each other about the normal value. If there is a small annual excess it means that many colder waves have passed over the United States, and if there is a small annual deficiency, that more warm waves have passed over the country. The annual departure is a guide to the interpretation of the kind of weather conditions that have prevailed, and its practical value is far greater than its apparent numerical size, when rightly interpreted. The departures of temperature and precipitation, monthly and annual, must be interpreted by the true significance of their component parts in a typical oscillation. The 11-year variation may be very small, but it is made up of numerous wide oscillations of short duration, and the mean departure is a key to their inner meaning.

Professor Newcomb's Criterion of the Mean Departure.

Before leaving the discussion of the temperature departures and residuals, it will be proper to summarize Professor Newcomb's criterion for the computation of a world-departure, that is, a variation common to the entire earth, and due to an external cause as the change in the intensity of solar radiation. One may conceive the earth as hung in space and affected as a whole by the intensity of the radiant heat energy that falls upon it. If this outside energy produces a simultaneous rise in the temperature of the atmosphere at the surface of the earth, it should be possible to compute the amount by combining stations in different parts of the world for the same interval of time. If this effect were a simple response to the outside cause, it would be an easy problem, but since it is complex it becomes an exceedingly difficult question how to discuss the observed departures and residuals. Supposing that the observations at each station to have been made *homogeneous*, it is evident that they can be combined in one summation only upon the following conditions: (1) The series of fluctuations depending upon solar action must be reduced to the *same period*, or else by taking the same phase at different intervals of time from the epoch, the summation will destroy the residuals by mere dislocation. (2) Since the same outside cause produces *inverted* effects in different parts of the atmosphere, an inversion of departures and residuals must be admitted. (3) The magnitude of the departures depends upon the place in the general circulation to such an extent that the local effect of oceans and continents must be considered in the method of collecting the data. Since the same outside cause produces opposite effects, in consequence of the general and local circulation, unless discrimination is made in the grouping of the data, a non sequitur in the argument follows. If the existing departures are summed together indiscriminately, making no allowance for periodic oscillations of *irregular lengths*, for *inversion effects* between the tropics and the temperate zones, for the local influence of land and water masses upon the *absorption of solar heat, and the radiation of the heat at terrestrial temperatures*, the surviving sum of the departures and residuals will be so nearly zero as to be regarded elusive and unimportant.

It may be remarked, in passing, that Professor Newcomb's paper does not sufficiently recognize these principles to do justice to his criterion. Since this method may properly be applied to many problems in meteorology, it should be fully understood, and the following statement of it is made, slightly changing the original notation. Let,

n = the number of stations in each time-term.
r = the number of time-terms (11-years, 3-years, year, etc.).
v_{nr} = the departures from a long-record normal.
τ_r = the mean departure in each term-time.
τ_o = the world-departure, or regional-departure.
$u_{nr} = v_{nr} - \tau_r$ = the residuals.
$v'_{nr} = v_{nr} - \tau_o$ = the purely accidental local departures.
$e = \tau_r - \tau_o$ = the mean accidental local regional departure.
$e^2 = \frac{\Sigma_n v'^2}{n^2} = \frac{\epsilon^2}{n}$ = the square of the mean v'.
$\epsilon^2 = \frac{\Sigma_n v'^2}{n} = ne^2$ = the mean square of v'.

Hence, $v = \tau_o + v'$, and $\tau = \tau_o + e$.

The original equation is by definition.

$$v_1 + v_2 + v_3 + \dots + v_n = \Sigma_n v = n\tau. \qquad (1)$$

Square this equation term by term, form the squares and the products, and take the sums, calling vv the successive pairs,

$$\Sigma_n^2 v^2 + 2\,\Sigma vv_1 = n^2 \Sigma \tau^2. \qquad (2)$$

If the variations v_1, v_2, v_3, etc. are *purely accidental*, there will be as many positive as negative values of vv_1, and the sum of the products will be zero,

$$2\,\Sigma vv_1 = 0. \qquad (3)$$

Hence, if the departures are purely accidental,

$$n^2 \Sigma \tau^2 - \Sigma_n v^2 = 0 = \Delta = \text{Criterion}. \qquad (4)$$

If $\Delta = 0$ the value of the regional departure is zero; if Δ is a *positive* quantity, there is a true regional-departure or a true world-departure; if Δ is a *negative* quantity, one regional-departure is hotter or colder at the expense of another regional-departure. Substitute $\tau_o + v'$ for v, and $\tau_o + e$ for τ in (4), in order to separate the purely accidental parts of the local and regional departures.

$$\Delta = n^2 \Sigma(\tau_o + e)^2 - \Sigma_n(\tau_o + v^1)^2. \qquad \text{Expand,} \qquad (5)$$

$$\Delta = n^2 \Sigma(\tau_o^2 + 2\tau_o e + e^2) - \Sigma_n(\tau_o^2 + 2\tau_o v' + v'^2). \qquad (6)$$

The terms $\Sigma 2\tau_0 e$ and $\Sigma 2\tau_0 v'$ are each equal to zero, and since $ne^2 = \Sigma_n v'^2$ by definition,

$$\Delta = n^2\tau_0^2 - n\tau_0^2 = n^2\Sigma\tau^2 - \Sigma_n v^2 = 0, \text{ for accidental } v_n. \qquad (7)$$

$$\Delta = n(n-1)\tau_0^2 = n^2\Sigma\tau^2 - \Sigma_n v^2, \text{ for } n \text{ stations.} \qquad (8)$$

Similarly,

$$\Delta_r = rn(n-1)\tau_0^2 = n^2\Sigma_r\tau^2 - \Sigma_{nr} v^2 = 0, \text{ for } r \text{ series.} \qquad (9)$$

This is Newcomb's Criterion for accidental departures for a large regional or world departure τ_0. (1) Take the mean of the departures v_n for the τ; square them and take the sum multiplied by n^2; (2) square all the v in the n-stations and r-time-terms and take the sum; (3) divide the difference by $rn(n-1)$ to find τ_0, the mean regional departure. These should be completed by *consecutive series* in succession, as 1872–76 for τ_0 at 1874, 1873–77 for τ_0 at 1875, and so on, thus eliminating all periods shorter than r time-terms, 5 years in this case.

The probable error of the world or regional departure from the normal is found as follows: The probable error is, by the theory of least squares,

$$u^2 = v^2 - \tau^2. \qquad (10)$$

Substitute $v = \tau_0 + v'$ and $\tau = \tau_0 + e$,

$$u^2 = v'^2 - e^2 - 2\tau_0(v' + e). \qquad (11)$$

In the summation the product $\Sigma 2\tau_0(v' + e) = 0$

$$\Sigma_n u^2 = \Sigma_n v'^2 - ne^2. \qquad (12)$$

Substitute $\Sigma_n v'^2 = n\epsilon^2$ and $ne^2 = \epsilon^2$,

$$\Sigma_n u^2 = n\epsilon^2 - \epsilon^2 = (n-1)\epsilon^2 = \Sigma_n v^2 - n\tau^2. \qquad (13)$$

Similarly for a series of r time-terms,

$$r(n-1)\epsilon_r^2 = \Sigma_{nr} v^2 - n\Sigma_r\tau^2, \qquad (14)$$

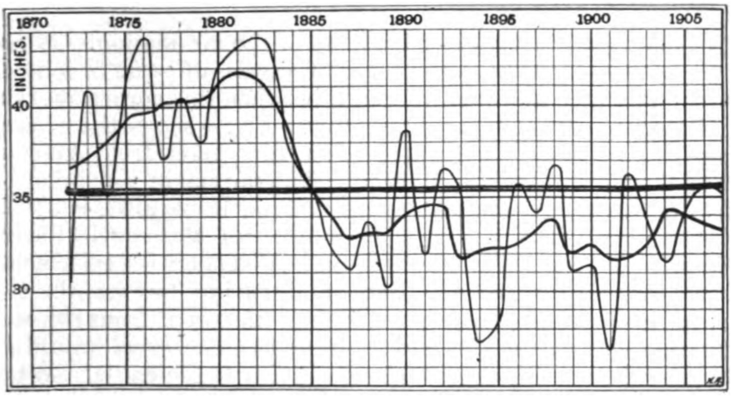
from which the value of ϵ or ϵ_r are found.

These mathematical principles are valuable in some cases of pure homogeneous data, simple definite period, no inversion effects and no complex absorption and radiation effects of land and water masses, but they must be applied with discrimination and knowledge of facts in order not to lead to a vanishing summation, and a non sequitur conclusion as to the meaning of the fluctuating departures and residuals in the observations. It is proper that meteorologists should approach these summations cautiously. At present they are engaged in making their records of observations homogeneous, and in studying the general principles of inversion, radiation and absorption, under the dominating influences of circulation.

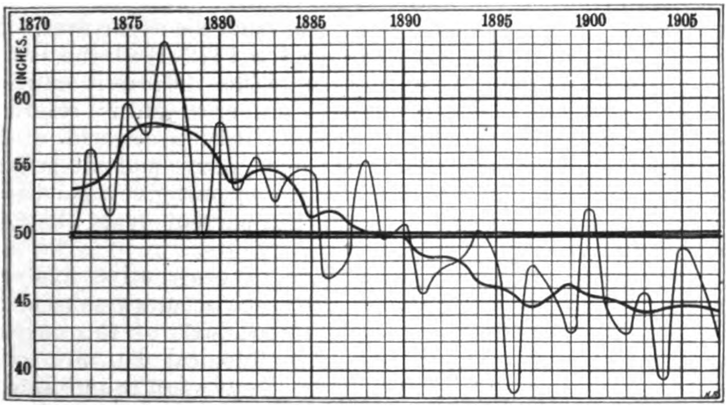
The Departures and Residuals of the Precipitation.

Unfortunately it is more difficult to know how to discuss the departures and residuals of the precipitation, because of the greater irregularity in this element due to transportation of

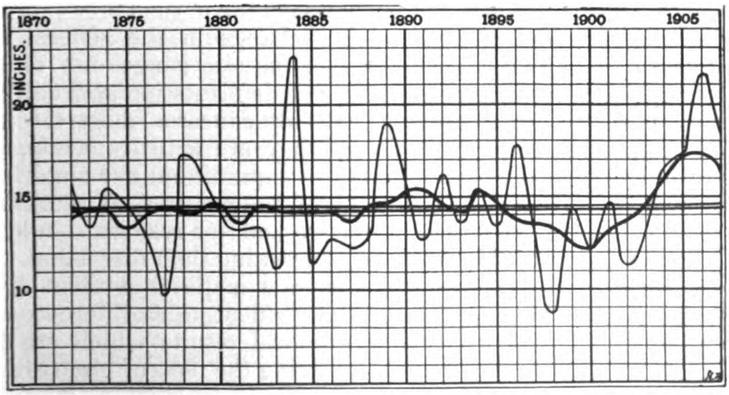
Fig. 4. *Typical examples of precipitation records from which to obtain normals, departures and residuals.*



Sec. 1.—Annual precipitation in the Lake Region and the central valleys. Heavy lines for the means of successive five-year groups.



Sec. 2.—Annual precipitation in the east Gulf States. Heavy lines for the means of the successive five-year groups.



Sec. 3.—Annual precipitation in the South Pacific States and southern Rocky Mountain Plateau. Heavy lines for the means of successive five-year groups.

aqueous vapor in the great currents of the circulation. It has been customary to take the mean of a series of years or months for the normal, and the difference between this normal and the individual values for the departures. Fig. 4 shows the general case that is to be considered, the data being taken from Abstract 3 of the Climatological Division. The normal of precipitation for the Lake Region and Central valleys, 1872–1907, is 35·55; for the east Gulf States it is 50·04; for the south Pacific States and southern Rocky Mountain Plateau it is 14·55 inches per year. If the normal line on fig. 4 lies between the two close parallel lines, the *departures* are measured from this normal to the crests of the annual line; the *residuals* would be measured from the consecutive mean line to the crests. When the normal and the consecutive mean line are practically coincident as in the section 3, the departures and the residuals agree together, and no question arises. When, as in sections 1 and 2, the normal line and the consecutive mean line do not agree, then the residuals are different from the departures. In such a case as the east Gulf States for 1872–1889 the entire system is *above* the normal, and for 1890–1907 it is entirely *below* the normal. It does not seem proper to confuse residuals with departures for practical purposes, because a series of departures all largely positive for a set of years, and all largely negative for a following set of years, does not give a good idea of the course of the phenomena in the current years that are within the memory of man.

It is not easy to see how the line of consecutive five-year means can be extended forward with such accuracy as to make it suitable for a computation of the residuals of the current month and year in which the Climatological data are to be published. It is proper to submit this question to public discussion, and an expression of opinion is solicited from engineers regarding the desirability of substituting *approximate residuals* for the wide departures at present in use. The question is not concerning the causes of the change in the normal precipitation in different series of years, such as change in the general circulation, change in the exposure of the rain gauges due to the growth of cities, nor of the effect of deforestation and cultivation of the soil upon climate. It only concerns the treatment of the records of precipitation as they are actually made. It is obvious that the departures of precipitation differ materially in principle from the departures of temperature as published in the Monthly Weather Review, and its readers should at least be aware of the problems concerning their discussion. If the printed departures stand as raw material without fixed principles of interpretation, it is evident that differences of opinion will arise regarding practical results which are due solely to different ways of interpreting the facts of observation.

ART. XXIII.—*On Mixed Crystals of Silver Sulphate and Dichromate;* by R. G. VAN NAME and ROWLAND S. BOSWORTH.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccviii.]

IN 1891 Retgers* described an attempt to form mixed crystals of silver chromate and sulphate by allowing an ammoniacal solution of the two salts to evaporate. The two silver salts were found to crystallize separately and no mixed crystals were obtained. The failure of this experiment makes it seem doubtful whether the sulphate and normal chromate of silver possess, to any appreciable extent, the property of forming mixed crystals together, especially since Retgers was unable to obtain mixed crystals of the corresponding sodium salts.

We have found, however, that if the solution be sufficiently acid, and the ratio of chromate to sulphate within certain narrow limits, well developed crystals are formed, of colors ranging from pale yellow through shades of orange and vermillion to a deep scarlet, according to the value of the ratio just mentioned. Analysis of these crystals shows that they consist of silver dichromate and normal silver sulphate in varying proportions. As these mixed crystals have not, so far as we know, been described heretofore, it has seemed desirable to carry out the following brief investigation of their properties.

A series of crystallizations was made at 25° starting with solutions of the same total acidity, about one fourth normal, but containing different proportions of the two acids. The change in concentration caused by the crystallization was kept as low as practicable by using in each experiment a large volume of solution, two liters, and so choosing the conditions that equilibrium was reached when only a small weight of crystals, usually less than three grams, had been formed. As will appear later, mixed crystals were only obtained when the molecular ratio of SO_4 to Cr_2O_7 in the solution was above 99 to 1. An increase in the proportion of Cr_2O_7 gave only pure crystals of silver dichromate, so that the investigation of solutions containing high proportions of dichromate was unnecessary. It was therefore possible to obtain a sufficient range of concentration of dichromate for all needed experiments by merely dissolving various amounts of silver chromate in the same volume of the standard sulphuric acid solution, previously warmed. When a higher concentration of silver was required silver sulphate was also added.

The different sulphuric acid solutions were adjusted to exactly the same strength by comparison with the same sodium hydroxide solution. Silver sulphate was prepared from the purchased salt by dissolving in sulphuric acid, precipitating by diluting with water, and washing on the filter until the filtrate showed no acidity. Silver chromate was prepared by evaporating an ammoniacal solution of the ordinary precipitated product, a method which gives the salt in a finely crystalline state, in which it is very easily washed.

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* Zeitschr. phys. Chem., viii, 52, 1891.

The method in detail was as follows: Two liters of the standard sulphuric acid solution were warmed to about 50° and the desired amounts of silver sulphate and chromate dissolved as described above. This solution was filtered while still warm into a large beaker, cooled to nearly 25°, and placed in the thermostat. A rotary stirrer kept the liquid in constant motion during its crystallization. After 24 hours, samples of the liquid were taken for analysis, and the crystals collected, washed, and dried at 130°. The crystals were small, and when examined under the microscope were found to be well developed and apparently free from inclusions of liquid.

In analyzing the solution Ag, SO_4, and Cr_2O_7 were determined in separate portions of 25^{cc} each, the first two by weighing as AgCl and $BaSO_4$ respectively, the last volumetrically by titrating the iodine set free from KI. The same methods were used in analyzing the crystals. The results are given in the accompanying table.

Owing to the small differences in composition between the different solutions analyzed, and to the high ratio of SO_4 to Cr_2O_7, experimental errors have a very disturbing effect, as is evident on comparing the values obtained, given in the first four columns of the table.* The next four columns contain the molecular ratios of SO_4 to Cr_2O_7 in the solution and crystals respectively. The ninth column gives the total acidity in equivalents per liter, calculated by subtracting the equivalent concentration of the silver from the sum of those of SO_4 and Cr_2O_7. The observed slight variations in the total acidity were probably caused in part by difference in the amount of evaporation which took place during the experiment, and in part by loss of chromic acid through the crystallization of dichromate.

In experiment I no chromate was present. Experiments II and III gave mixed crystals containing different proportions of dichromate and of different color, vermillion in II and deep

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* Thus in experiment IV the proportion of dichromate in the solution must in reality have been larger than in experiment II, although the analysis, probably owing to a summation of errors, indicated the reverse. The large effect of certain errors is well illustrated by the fact that a difference of less than $0{\cdot}2^{cc}$ in the amount of thiosulphate used in experiment IV would have eliminated this inconsistency.

Formation of Mixed Crystals of Ag_2SO_4 and $Ag_2Cr_2O_7$ at 25°.

	Analysis of 25				Molecular ratio				Acidity equiv. per liter	Solid phase
	Ag.	SO_4	$Na_2S_2O_3 \rightleftharpoons Cr_2O_7$		Solution		Crystals			
	grm.	grm.	cc.	grm.	SO_4	Cr_2O_7	SO_4	Cr_2O_7		
I	0·1621	0·3690			100·0	0·0	100·0	0·0	0·2476	Ag_2SO_4
II	0·1645	0·3693	2·41	0·0074	99·10	0·90	98·8	1·2	0·2496	Mixed crystals
III	0·1621	0·3666	2·41	0·0074	99·09	0·91	95·9	4·1	0·2484	Mixed crystals (trace of $Ag_2Cr_2O_7$)
IV	0·1612	0·3666	2·23	0·0068	99·2	0·8	84·5	15·5	0·2482	Mixed crystals + $Ag_2Cr_2O_7$
V	0·1630	0·3617	2·46	0·0076	99·0	1·0	0·0	100·0	0·2440	$Ag_2Cr_2O_7$
VI	0·1381	0·3476	3·00	0·0093	98·8	1·2	0·0	100·0	0·2420	$Ag_2Cr_2O_7$
VII	0 ·0583		7·13	0·0230	96·7*	3·4*	0·0	100·0		$Ag_2Cr_2O_7$

* Calculated from the average acidity.

scarlet in III. With the scarlet crystals produced in experiment III was mingled a minute quantity of much darker crystals. These were again obtained in experiment IV in large amount, together with mixed crystals of the same scarlet color as before. The three remaining experiments gave crystals in which no sulphate could be detected, and which, on complete analysis, were found to be pure silver dichromate. The color of these crystals, deep wine red by transmitted light, metallic gray by reflected light, was the same as that of the darker crystals obtained in experiments III and IV. With much labor about 15 milligrams of the latter crystals were separated under the microscope from the scarlet crystals with which they were mingled, and were carefully tested for sulphate without result, thus showing that they too consisted of pure silver dichromate.

The mixed crystals, as proved by the usual goniometric and optical tests, were orthorhombic, having the same pyramidal habit and nearly the same crystal angles as those given by

Mitscherlich* for silver sulphate. The silver dichromate was found to be triclinic, as stated by Tschermacher† and Schabus.‡

From the above results it is clear that silver sulphate is "insoluble" in the ordinary triclinic silver dichromate and that the formation of mixed crystals is due to a rather limited solubility of silver dichromate in orthorhombic silver sulphate. The extent of this solubility at 25°, i. e. the composition of the saturated mixed crystals, must be very near the value given by the analysis of the crystals in experiment III, since the pure silver dichromate mingled with the mixed crystals was present in too small a quantity to seriously affect the result, and would, moreover, tend to compensate for the error introduced by the gradual change in the composition of the solution during the crystallization. As a check upon this result an analysis was made of another sample of approximately saturated mixed crystals prepared in a different experiment. The value obtained was 4·4 molecular per cent of dichromate, against 4·1 per cent in experiment III. On account of the small amount of material available for this last analysis, the result is probably less accurate than that obtained in experiment III.

To determine the effect of an increase in acidity a series of crystallizations was made at 25° from solutions whose total acidity was approximately twice equivalent normal, prepared by mixing standard solutions of the two acids in a known ratio. The crystals were not analyzed as the two kinds could readily be distinguished by their color. An initial ratio of 1·2 equivalents of Cr_2O_7 to 98·8 of SO_4 gave both dichromate and mixed crystals, a ratio of 1·1 to 98·9, mixed crystals only. The composition of the solution which is in equilibrium with both kinds of crystals must evidently lie between these limits.

The above facts may be briefly summarized as follows:
The mixed crystals formed at 25° resemble the orthorhombic silver sulphate in crystal form and habit, and contain a maximum of about 4 molecules of dichromate to 96 of sulphate. The solution which is in equilibrium with these saturated mixed crystals, and at the same time with pure silver dichromate, has a composition, expressed in molecular per cent of Cr_2O_7 (equivalents of Cr_2O_7 per 100 equivalents of the mixture of Cr_2O_7 and SO_4), lying between the limits 0·90 and 0·95 when the total acidity of the solution is one fourth normal, and between 1·1 and 1·2 when the acidity is twice normal.

The authors wish to express their thanks to Professor Edward S. Dana for his kind assistance in the crystallographic and optical tests.

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* Pogg. Ann., xii, 137, 1828.

† Phil. Mag., [2], i, 345, 1827.

‡ "Bestimmung der Krystallgestalten in chemischen Laboratorien erzeugter Producte," Wien, 1855, page 185.

ART. XXIV.—*Osteology and Affinities of the Genus Stenomylus;* by FREDERIC B. LOOMIS.

DURING the summer of 1907 the Amherst College field party while prospecting in the sandstones of the Lower Harrison levels some five miles to the southeast of the Agate Spring postoffice, Sioux Co., Nebraska, found fragments of a Stenomylus smaller than the *S. gracilis* then known. During that season a few badly shattered remains were collected, after which work was continued in other sections of the field. On returning the next season, however, the same levels were further excavated, on which it developed that there was a veritable quarry of these skeletons at this locality; for no less than eighteen skulls, together with enough disarticulated bones to represent the complete skeletons, were collected from one pocket, and in an adjacent portion of the hill three complete skeletons were found. Following this the Yale University party collected three skeletons, the American Museum party five or six skeletons, and the Carnegie Museum party five or six. During the season of 1909 the Carnegie Museum again collected in this quarry, obtaining a large number of skeletons. Thus already not less than forty skeletons, and I should estimate many more, have been taken out, and as the specimens are found along over 150 feet of the face of the hill, I see no reason why as many more complete skeletons should not be obtained from the same source. With this wonderful and well-distributed material there is every reason that a complete description should be made both for identification, osteological study, and comparison.

The quarry.—The Stenomylus quarry is located some five miles due southeast of Agate Spring postoffice, and about one and a half miles up the "draw" south of the upper Harris place, and about the same distance a little east of south from the famous Agate Springs quarry of the Carnegie Museum. The horizon is in the Lower Harrison beds about 75 feet from their upper boundary. The matrix is a fine, homogeneous, well-bedded, soft sandstone, which differs materially from the much coarser and more irregularly bedded sandstone typical of these beds. These fine sands are about 100 feet in thickness and seem to have a limited extension, being traced only about three-fourths of a mile to the south and thinning out very soon in the other directions. To the east the Upper Harrison beds directly overlie these fine sandstones. The Stenomylus remains occur in two levels; the one about four feet above the other, and both some 70 feet below the top. In the lower of the two levels the skeletons are pretty much disassociated, while in the upper level, when a specimen is found, it is usually a more or less complete skeleton. Above these levels there is nothing approaching a bone bed, but occasionally Stenomylus remains are, however, found throughout the whole thickness of the fine sandstones. The even sorting and bedding of these sands indicate deposition in comparatively quiet water; and as the Lower Harrison beds seem to be flood-plain deposits, it would appear that these finer sandstones were laid down in some more sheltered area behind a barrier, which barrier must have been of considerable extent and height to account for the deposition of about 100 feet of uniform material. The Stenomylus remains presumably floated to their final resting place, and each of the two bone-bearing levels represents the destruction of scores of individuals. The simplest reconstruction of conditions would picture a herd of the unfortunate creatures during the distress of a great flood taking refuge on the highest available point of land; which, however, proved too low, and after surrounding them the rising waters drowned and carried off the whole herd, males and females, young and old. The carcasses then floated down stream and were accumulated in the backwater, where they were then buried in the accumulating sands. This was apparently a relatively rapid accumulation, for the carcasses, especially in the upper level, are not pulled to pieces by carnivores. The position of the head in the type (fig. 1) is characteristic of a good many of the skeletons, and I believe is common among drowned animals. Presumably the same point of land in two seasons proved to be a fatal trap for herds of these delicate creatures, and afterward it was only occasionally that an individual carcass was washed into the area where these sands were accumulating. Remains of other animals are very scarce in these sandstones, but a few isolated bones, the Diceratherium, and the major part of a skeleton of *Daphœnodon superbus* Peterson, and a few bird bones do occur with the Stenomylus bones, and confirm the stratigraphic determination of Lower Harrison.

Plan.—In considering the material it seems best to give a detailed osteological description of this species, followed by the distinctive comparisons of the three known species, and finally to consider the affinities and phylogenetic position of the genus.

Stenomylus hitchcocki sp. nov.

Type.—The type is a complete skeleton, all the bones articulated and in place, No. 2059 of the Amherst College collection. With this are used six skulls and a dozen upper and lower jaws, together with some four disarticulated skeletons and iso-

Fig. 1.

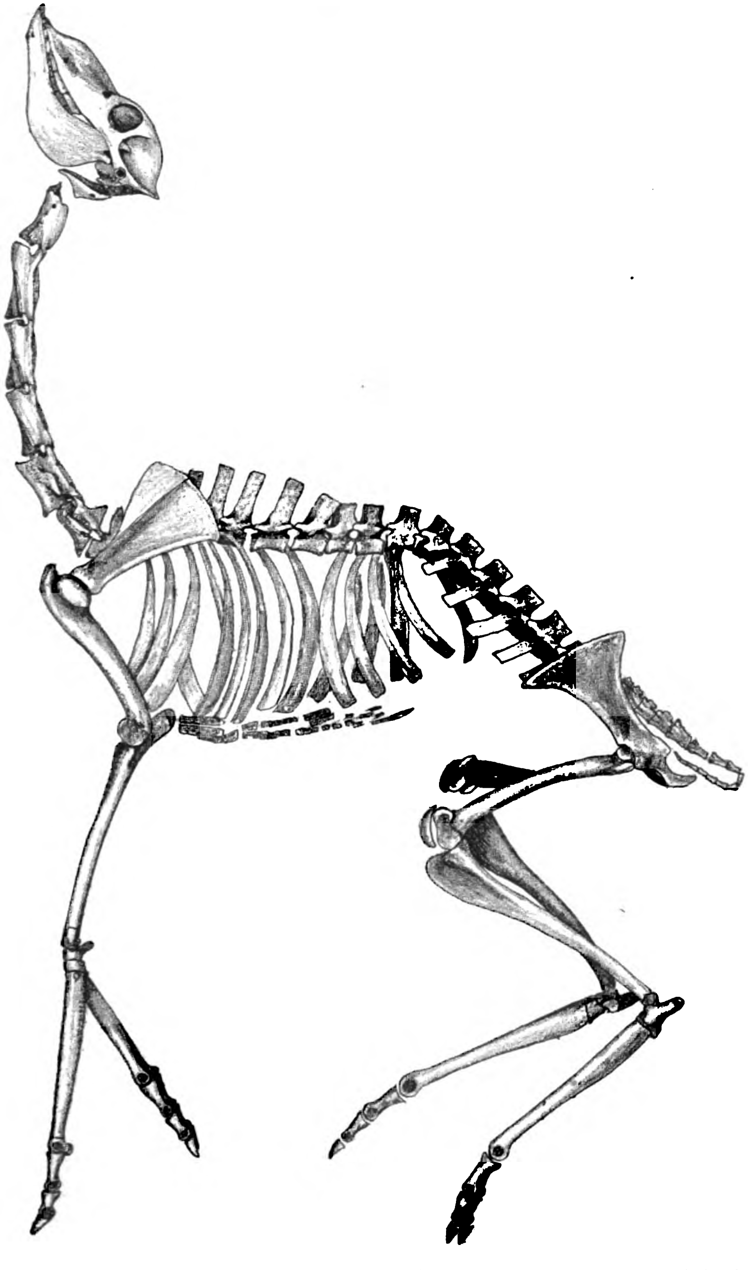

Fig. 1. *Stenomylus hitchcocki*, type specimen as seen lying in the original matrix. × 1/6.

lated bones, and the four complete skeletons of the American Museum. In the series are individuals which are interpreted as male and female, and a number of young having but their milk dentition. The species is named after Dr. Edward Hitchcock, whose work in comparative anatomy and paleontology was the stimulus for the expedition and the work of the writer. The individual used for the type is one which has just reached maturity as shown by having all the molars worn, but that is all, for the epiphyses of several of the limb bones are still free from their shafts. The position of the type specimen is that of an animal which has just laid down with legs outstretched and head thrown back, or probably better, of an animal which has been drowned, but is natural enough so that we can readily get measurements of the whole animal.

Height at the shoulders	684^{mm}	(27 in.)
Length of head	175^{mm}	(7 in.)
Length of neck	380^{mm}	(13½ in.)
Length of body	433^{mm}	(17 in.)
Length of tail	155^{mm}	(6¼ in.)

This individual is slightly smaller and lighter in build than some of the others, and I have interpreted it as a female. In comparing the measurements with those of other Tylopoda it will be apparent that the body is unusually short; the limbs, therefore, appear long, though when compared with the length of the humerus, they are but little longer relatively than those of Pöebrotherium. The neck in conjunction with the increase of limb is also a little longer than that of the Oligocene tylopod.

Skull.—The relatively small skull has a wide cranium but a narrow compressed muzzle. The basicranial axis is only slightly bent. In conformity to the lateral compression of the muzzle the nasals are slender splints which diverge when they reach the wedge-shaped anterior end of the frontals. These latter bones are very wide, overhanging the orbits which stand out from either side of the skull. The two parietals are fused medianly and make a bone of considerable extent, on the posterior half of which is situated a low sagittal crest, which unites with the strong lambdoidal crest. This latter crest is high and projects strongly backward, overhanging the occiput. The premaxillæ rise rapidly on the high muzzle, expanding somewhat at the upper end. It is the maxilla which makes up the greater part of the side of the snout and in this bone are two deep pits on either side, the first a preorbital pit, a little in front of the orbit and high up on the muzzle; the second a subnasal pit, considerably in front of the former and much lower on the muzzle. The preorbital pit, situated some 20^{mm}

in front of the orbit, is an oval depression some 25^{mm} long by 12^{mm} high, and so deep that between the two sides there is but 9^{mm}, which must nearly close the olfactory space within the muzzle. In like manner the subnasal pit is well down on the side of the snout, and extends from over premolar 1 to over premolar 4, being about the same size as is the preorbital pit. In the latter case the depth of the pits is, however, such that there is but six millimeters between the two sides of the skull opposite the bottom of the pits, so they must practically close the internal olfactory passage in that vicinity. Similar, though less developed, pits occur in other primitive genera among the Tylopoda: and the preorbital pit is also characteristic of several species of horses of the Oligocene genus, Mesohippus. The pits were probably occupied by glandular structures, but pits of such extent are not known to the writer among recent genera. The pit occupied by odor-secreting glands among certain artiodactyls may be cited as a counterpart, but it is hard to believe that odor glands in any species became as large as those pits would indicate.

FIG. 2.

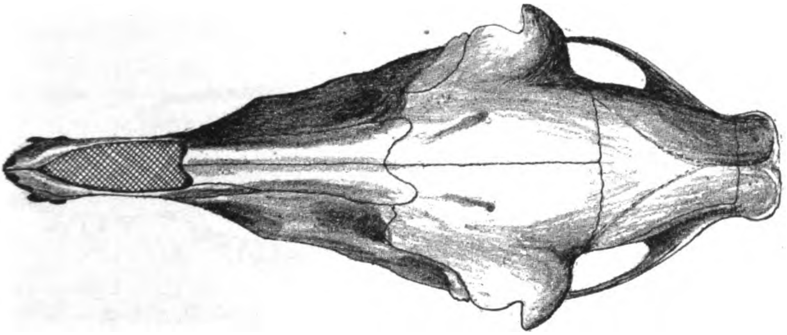

FIG. 2. *Stenomylus hitchcocki*, skull seen from above. × 1/2.

As is usual for members of the tylopod phylum, there is an orbital vacuity of some extent at the juncture of the maxilla, nasal and lacrymal bones. The lacrymal bone itself is relatively large, extending considerably in front of the orbit. The margin of the orbit is sharply outlined and smooth except that on the lacrymal there are two deep and characteristic notches. The lacrymal foramen is well within the border of the orbit. The jugal bone bounds the front and lower part of the orbit, meeting in the rear the broad postorbital process of the frontal. The squamosum is of moderate dimensions, and carries a slender zygomatic process. On the lower surface the glenoid articular surface can scarcely be described as a cavity, making as it does rather a wide convex rectangular area which must have allowed very free movement to the lower jaw, both laterally and vertically. The postglenoid facet is practically vertical and closely appressed to the bulla, the two facets (glenoid and postglenoid) being separated by a gap, as is the case in modern camels. The tympanic bone is fused to the squamosum, the external auditory meatus being a closed slightly projecting ring; while the greatly inflated bulla is filled with cancellous bone, as is the case in Tylopoda generally. The bulla is also fused to the paroccipital process for most of its length. The occipital bones are all fused, and the occiput is narrow and small. The two condyles are sessile, and do not project behind the plane of the occiput. Below, their facets do not quite meet, being separated by a narrow groove of about a millimeter, the groove being, however, much wider in youthful specimens. The pterygoids unite with the palatines to make deep plates projecting below the base of the skull. The posterior nares open between the palatines so far forward as to make a very short hard palate. The front of the naral opening is opposite the front of the second molar, which in general is very far forward for this opening. However, in the Tylopoda generally it is characteristic to have the posterior nares open well forward: so that this genus simply shows a somewhat higher specialization in this feature. I feel that the compression of the muzzle by the preorbital and subnasal pits tends to cause the posterior opening of the respiratory passage to emerge into the mouth as far forward as possible.

Fig. 3.

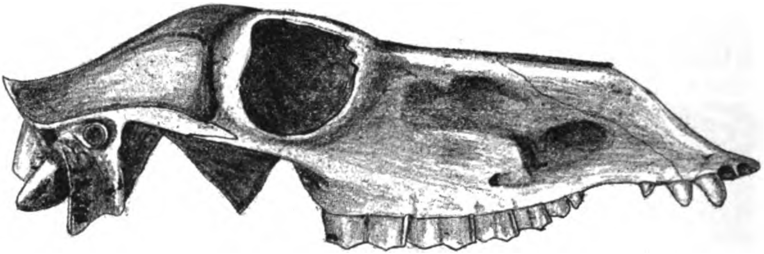

Fig. 3. *Stenomylus hitchcocki*, side view of the skull. × 1/2.

The mandible is decidedly deep for so slender a creature, but the reason for this is readily seen in the extreme hypsodont condition of the teeth, which in a recently mature individual extend nearly to the bottom of the jaw. The symphysis is of moderate length and spout-like in form. The angle of the mandible is not produced into the upward hook-like process so common among the tylopods but shows simply a slight projection (see fig. 6) at that point. The coronoid process is short and slender, being slightly recurved. The articular condyle is broad and slightly concave, the postglenoid facet being large and resembling that of the llama.

The following measurements give the proportions of the skull:

Specimen	Length incisor to occ. condyle	Length premolar 2-molar 3	Orbit weight by width	Width across orbits	Width across molars 2	Age	Sex
S. hitchcocki type	166	60.5	27 × 26·5			barely mature	♀
S. hitchcocki 2019	179	58	24 × 28	67	37	old	♀
S. hitchcocki 1090	191	67	28 × 29	68		mature	♂
S. hitchcocki 2009		33 p^{2-4}				milk	
S. crassipes	211	78				mature	
S. gracilis		80	27 × 26	95	57	mature	

Age.—The series of adult skulls fall into two classes irrespective of the amount of wear of the teeth, namely smaller, lighter ones, which I should interpret as female; and larger, heavier ones, which would be males. Aside from these characters of relative proportion I have found no distinctive sex characters. As all the associated skeletons must have been accumulated at one time, and births presumably took place in the spring, such individuals as show differences in age must have been a year apart. On this basis, the youngest, which have the entire milk dentition and the first molar just showing, would be one year old; while the next set, in which the third molar is just up, would be two years old, at which time they have reached nearly full size, as shown by such a specimen as the type. How long they lived would be difficult to estimate, but every indication points to very rapid wear of the teeth; so that five or six years seem to me to represent the probable length of life of the older individuals studied.

Dentition.—The dental formula is i.$\frac{3}{3}$c.$\frac{1}{1}$p.$\frac{4}{4}$m.$\frac{3}{3}$ = $\frac{22}{22}$ = 44, which is the full and primitive set. The upper incisors are simple chisel-shaped teeth, entirely unreduced and crowded into a full series. The upper canine is laterally compressed, making it into a subincisiform tooth, which stands a little apart from the incisors, however. Behind the canine there is a moderate diastema which precedes the reduced two-rooted first premolar, while behind this tooth a much greater diastema occurs, separating it widely from the second premolar, which, like its predecessor, is reduced and two-rooted. The third premolar follows without any diastema, and is a narrow elongated tooth, but with none of the specializations of the teeth which follow it. The fourth premolar has acquired the selenodont character, though but single-lobed, its inner and outer cusps having developed into high crescentric ridges, with a deep pit between. The three molars are all extremely hypsodont, which is one of the most marked features of the genus. Each tooth is very simple, consisting of two lobes, each with a deep pit in it. There is no cement in the valleys. Each tooth is nearly flat on the outer side, there being but a slight convexity outside the paracone and metacone, and no column except that the anterior border of each molar is developed into a parastyle. The widest portion of the series is at the second lobe of the first molar. The crown of each molar is greatly developed in height, as is seen in the section of a second molar (fig. 5), the top being slightly narrower than the base, so that as they wear the teeth appear relatively wider. A slightly worn second upper molar of *S. hitchcocki* has a crown 23^{mm} high which contained a pit 19^{mm} deep, these pits in the upper molars being materially deeper than in the lower molars. The successive molars seem to come up slowly or else the wear is very rapid, for when molar 3 is but slightly worn the first molar is down to the bottom of the pit. In addition to the considerable height of the crown the upper part of the pulp cavity fills in with dentine, so that some time after the bottom of the pit is reached the tooth still has a solid center, in the middle of which is a small discolored "mark." Inasmuch as the wear seems to continue considerably below the base of

FIG. 4.

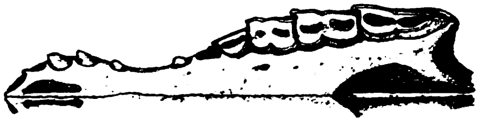

FIG. 4. *Stenomylus hitchcocki*, upper dentition and palate. × 1/2.

FIG. 5.

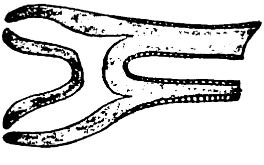

FIG. 5. *Stenomylus hitchcocki*, section of upper second molar, to show depth of pit. ×1/1.

the pit, the tooth in addition to its great height must increase still more by growth at the base during life.

The lower dentition.—The lower incisors are flattened and expanded at the top so that each successive incisor slightly overlaps the preceding one. The laterally compressed canine is grouped with the incisors and has assumed the incisiform character completely. Even the first premolar is semi-incisiform and stands close behind the canine, being thus in the incisor group. Behind this there is a considerable gap in front of the second premolar, which, though two-rooted, is considerably reduced. Behind this in turn occurs a wide diastema followed by the small but sharp third molar. It is only the fourth premolar which is to any degree functional as a grinding tooth, and this is a short, narrow, single-cusped tooth without any pit, of molariform adaptation. The three molars, however, are developed into deep hypsodont and compressed teeth, each with its deep pits. The first molar is the smallest of the three, consisting of two lobes, which like the others have a straight face on the inner side, there being no columns except the parastyle on the front margin of each molar. This tooth cuts the gum apparently at about the end of the first year and wears very rapidly, for when the third molar appears this tooth has worn below the base of the pit; but it is to be remembered that in the lower teeth the pits are not nearly as deep as in the upper molars. While the second lower molar is somewhat larger, it is otherwise like the first. But the third molar has three lobes, the last one being only a little smaller than the two preceding it. The extreme depth of this tooth is shown by the illustration (fig. 7), which is a typical young specimen of *S. hitchcocki*, and shows that in a crown 34^{mm} high the pit is

FIG. 6.

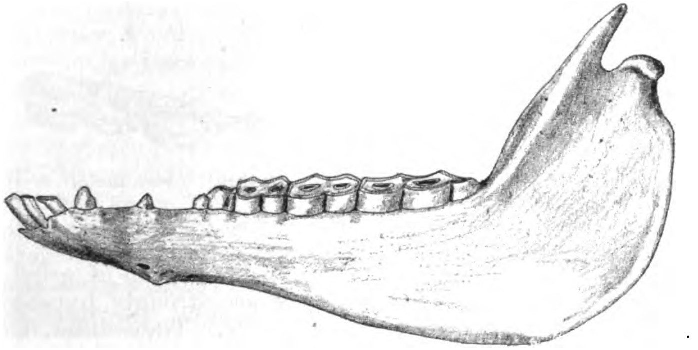

FIG. 6. *Stenomylus hitchcocki*, mandible with lower dentition. ×1/2.

but 9^{mm} deep. However, the tooth is available for much greater wear than the depth of the pit; for as age increases the pulp cavity fills with dentine and makes some 18^{mm} more available. The great height of these teeth is the cause of the great depth of the lower jaw noticed in the description of the mandible.

Milk dentition.—Young jaws are found in surprisingly large numbers, practically all of them being of about the same age, and showing the full milk dentition, together with the unworn first molar. These skulls are entirely disarticulated, and I have seen no incisor or canines of the upper jaw, though they were doubtless there. The first upper premolar is situated near the canine and behind it is a considerable diastema, between it and the second small pointed premolar. It is on the third and fourth of this series that the burden of grinding is thrown. Like adult molars, they are strongly hypsodont with high crescentric crests and deep pits. They differ, however, in having the outer face more convex over the paracone and metacone, and in having a well-developed mesostyle as well as a parastyle; from which it may be concluded that these features were also present on the teeth of the ancestral form. The third and fourth deciduous premolars are each two-lobed and in general resemble the permanent molars.

FIG. 7.

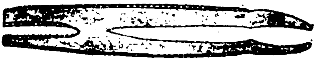

FIG. 8.

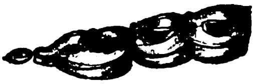

FIG. 7. *Stenomylus hitchcocki*, section of third lower molar to show depth of pit. ×1/1.
FIG. 8. Upper premolars of the milk dentition. ×1/2.

FIG. 9.

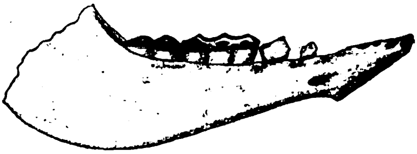

FIG. 9. *Stenomylus hitchcocki*, mandible with the milk dentition. ×1/2.

Lower jaws are usually the better preserved, the alveoli for the three incisors and the canine being present on several specimens. The canine is grouped with the incisors as in the adult. The first premolar is represented by a tiny alveolus scarcely larger than a pin hole, from which I judge that the tooth was vestigial. The second premolar stands isolated with a considerable diastema on either side of it, and like the third premolar is still a single-cusped tooth. The grinding tooth of the lower jaw is the fourth premolar, and this is developed as a large three-lobed, molariform tooth, with high crescentic cusps, and deep pits in each lobe. In all the specimens this tooth is well worn as though it had been used for grinding grass some time, which is the reason that I have assigned the age of one year to the individuals with this and the first molar just showing, as is uniformly the case.

Cervical vertebræ.—The neck as a whole is long and slender, each constituent vertebra being markedly elongated, as is usual among Tylopoda. The atlas is relatively long and narrow, the anterior cotyli being deeply excavated to make the articulation for the occipital condyles. In the lower side the two articular facets are separated by a groove in *S. hitchcocki* (confluent in *S. crassipes*), while on the upper side the two cotyli are separated by a wide notch. The posterior ends of the transverse processes are prolonged backward to make short horn-like projections, which extend behind the facets for the axis much as in Pöebrotherium. The posterior facet for the axis is high and inflexed along the upper border, for the under side of the odontoid process. The edges of the transverse processes make a nearly straight line, in contrast to the sinuous one commonly found. The vertebrarterial canal enters the neural pedicle just to one side of the axial facet and passing through the arch comes out again about the middle of the centrum. The first spinal nerve had its exit adjacent to the anterior opening of the vertebrarterial canal.

FIG. 10.

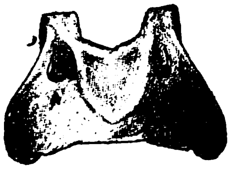

FIG. 11.

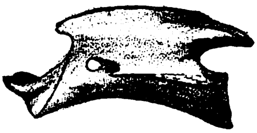

FIG. 10. *Stenomylus hitchcocki*, atlas seen from the dorsal side. × 1/2.
FIG. 11. Axis seen from the side. × 1/2.

The axis is also a long and slender bone, with a long, low spinous process ending to the rear in two small tubercles, a feature very characteristic of the camels. The transverse processes begin just in front of the middle of the centrum and make moderately expanded wings to either side, their outer edges being slightly flexed downward. The anterior facet for the atlas is a wide concave face extending in a trifle over half a circle, and dying out on the neural arches. The odontoid process is short and thick with a tubercle on its upper surface. In this the genus differs from the early tylopods, which have a semicylindrical odontoid, while that of the modern genera is spout-like. The vertebrarterial canal is confluent with the neural canal through the posterior third of the vertebra, then enters the pedicle of the neural arch, passing obliquely through and coming out about a third of the way from the front of the centrum. Just in front of the vertebrarterial foramen there is a wide opening for the exit of the second spinal nerve.

The third, fourth and fifth cervicals are so similar that they may be treated together. They are all long and slender, having only the smallest vestiges of a spinous process, in which feature they resemble the modern camels, even having the characteristic to a more marked degree than any of the other genera in the family. The transverse processes, expanding wing-like on either side, extend the whole length of the centrum, and then are prolonged into slender projections as seen in fig. 12. These transverse processes do not have the anterior portion of the wing prolonged into a distinct lobe, as is the case in the modern Tylopoda; but rather have the lobe barely indicated, as is the case in Pöebrotherium and Oxydactylus. A ventral keel develops on the posterior third of the centrum, expanding to the rear until it is very prominent. In none of these three vertebræ is the vertebrarterial canal visible externally. On cervicals 3–7 the anterior of the centrum is moderately convex, the posterior end concave.

The sixth cervical is markedly different from the others. First its dorsal spine is vestigial, which is well developed in the modern camels and in Pöebrotherium: then the transverse process is a short thin plate the distal end of which is bent backward. The interior lamellæ are developed into wide plates which extend the whole length of the centrum and project downward. These are not, however, divided into an anterior and posterior lobes as in the modern tylopods, but have a straight lower border as is the case in Pöebrotherium. The vertebrarterial canal enters the base of the neural pedicle at the rear and penetrates the entire length, leaving just under the prezygaphysis.

Fig. 12.

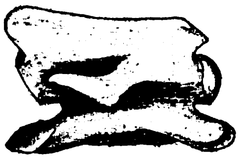

Fig. 12. *Stenomylus hitchcocki*, sixth cervical seen from the side. × 1/2.

The seventh cervical is much shorter than the others, and has a moderate neural spine. The transverse processes are developed as wings to either side and about half the length of the centrum, the outer margin being prolonged fore and aft and thickened. The wide posterior facet is placed obliquely to the length of the centrum, indicating a marked upward bend to the neck, so it is fair to conclude that the head was carried high. On the rear there are facets for the first ribs.

From the foregoing it is clear that this genus in such deep-seated characters as the position of the vertebrarterial canal, the reduction of the neural spines, and the characters of the transverse processes, relates itself closely to the Tylopoda, having especial affinity to the primitive genus Pöebrotherium.

The following measurements give the relative sizes of the various vertebræ in the three known species and in Pöebrotherium.

Length of Centrum × Width of Vertebra.

	1st.	2d.	3rd.	4th.	5th.	6th.	7th.
S. hitchcocki	33 long	54	68	58	54	49	35
	39 wide	29	41	37	37	37	40
S. crassipes	35	62	67	54		48	
	51	33	35		38	45	
S. gracilis					75	72	
P. wilsoni	36	66	63	58	56	45	36

Dorsal vertebræ.—The dorsal series consists of twelve vertebræ, measuring 242mm. The neural spines are all wide thin plates, so closely set in front as to leave almost no intervals between vertebræ, and reaching a maximum in height on the fifth dorsal, from which point on they are lower with increasing intervals between successive spines. The anticlinal vertebra is the eleventh dorsal. Metapophyses appear first on the eighth dorsal and occur on each successive centrum, situated each time a little higher and further forward, until on the eleventh the metapophysis unites with the prezygapophysis and together they make a concave facet which incloses the cylindrical postzygapophysis.

FIG. 13.

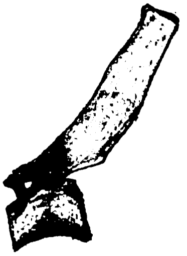

FIG. 13. *Stenomylus hitchcocki*, sixth dorsal seen from the side. × 1/2.

Lumbar vertebræ—The lumbar series consists of seven vertebræ, which total 190mm in length. Each one is characterized by having the above described interlocking series of concave prezygapophyses and cylindrical postzygapophyses as is typical of Tylopoda generally. While the neural spines only rise to moderate heights, they are wide, thin plates, considerably expanded above. The transverse processes extend, attaining the (for so small a form as *S. hitchcocki*) considerable length of 34^{mm}.

Sacrum.—The sacrum consists of four fused vertebræ having a total length of 59^{mm} and a width of 62^{mm}. The first of the component vertebræ sends out a stout and much expanded pleurapophysis to receive the ilium. To this is added the smaller but still stout pleurapophysis of the second sacral vertebra. These two sacrals are heavy, but the two posterior vertebræ having only to support the tail are reduced and have become very slender.

Caudal vertebræ.—The tail is supported by 14 vertebræ, of which the proximal ones are short and wide with well-marked transverse processes. Beginning with the seventh, however, the vertebræ are without transverse processes, and become approximately cylindrical rods, the last one being but 5^{mm} long and but 1^{mm} in diameter. The whole series measures 170^{mm}, indicating a tail of moderate length.

Ribs.—The first of the ribs is short and stocky, while the succeeding eleven are thin and wide (though not so wide as in the living camels), the interval between succeeding ribs being about half the width of the rib itself. A typical rib measures 175^{mm} long by 18 wide. Each rib has two heads rather close together, followed by a narrow abruptly curving neck, and then expands and stretches in a gentle curve toward the sternum. The uncrushed ribs show the body to have been decidedly narrow and moderately deep. The first five ribs were attached directly to the sternum by short calcified costal cartilages; the sixth and seventh by longer calcified cartilages; and the succeeding three are connected by long costal cartilages to each other and indirectly to the sternum; while the eleventh and twelfth are free ribs.

Sternum.—The sternum consists of a slender presternum of 22^{mm} length, followed by five wide sternal segments fused to each other. Opposite the point of union of each two segments the margin is expanded and offers an attachment for the costal cartilages. The sixth joint receives the two longer costal cartilages. Finally there is the xiphisternum, a thin expanded lamella of bone extending some 42^{mm} behind the rest of the sternum.

Fore limb.—The scapula is relatively long and narrow, the anterior margin extending upward in a decidedly concave curve, while the posterior margin is bounded by a like though less concave curve. The high spinous crest divides the blade into a smaller prescapular and a larger postscapular fossa, the latter being bounded on the outside by a raised ridge running along the posterior margin. Along the upper edge, the spine of the scapula is thickened and rugose for muscular attachments. Proximally it extends forward, making a slender acromian process which does not extend quite to the level of the glenoid fossa. The coracoid process is of but moderate dimensions and rolled inward, making a hook-like process. The shallow glenoid fossa is wider than high in the ratio of 4 to 3.

FIG. 14.

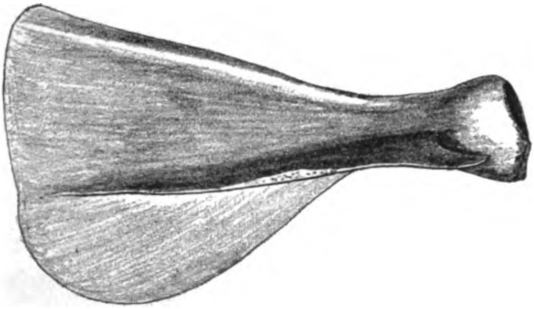

FIG. 14. *Stenomylus hitchcocki*, scapula seen from the dorsal side. x 1/2.

The humerus is slender and moderately long, the shaft having a well-marked sigmoid curvature. Corresponding to the shallow glenoid, the sessile head is but moderately convex. The greater tuberosity spreads along fully half of the width of the head, rising high above it, and overhanging the narrow bicipital groove; while the low lesser tuberosity of only half the width of its neighbor bounds the groove on the inner side. The bicipital groove when viewed from the front is seen to lie just to the inner side of the median line; and while narrow at the bottom, it expands up onto the lesser tuberosity, so that its width is about equal to that of the tuberosity. There is no trace of the bicipital tubercle dividing the groove into two

FIG. 15.

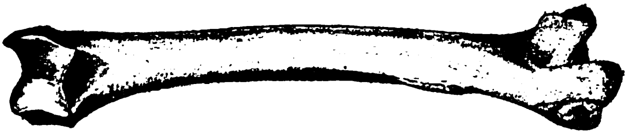

FIG. 15. *Stenomylus hitchcocki*, humerus, seen from the dorsal side. x 1/2.

parts as in modern camels. The deltoid ridge is well-marked, rising just under the head and reaching down to about the middle of the shaft. The supinator ridge is barely visible. The trochlea stands at almost right angle to the length of the shaft, is a little higher on its inner than on its outer margin, and has the intertrochlear ridge but feebly developed and situated near the middle of the ulnar side. The anconeal fossa is low and deep, but does not perforate the shaft.

The radius and ulna are completely fused throughout their entire length, thus making a long, slender curved shaft. Using the length of the humerus as a unit, the length of the ulnar-radius would be 1·38, which is relatively longer than is the case in Pöebrotherium (1·15) or the modern camel (1·25), but does not compare with the length of Oxydactylus. At both the upper and lower ends of the radius occurs a groove indicating the original boundaries of the ulna, the lower end of the groove penetrating so as to make a complete foramen. The compressed olecranon process is moderately high and wide, the upper anterior edge having in it a wide groove for the extensor tendon.* The humeral facets on the ulna are confined to the superior border of the sigmoid notch and are not confluent with the facets on the inferior border on either the inner or outer side. To this statement I found in ten cases but one exception, in which case the upper facet was confluent with the lower along the inner side of the sigmoid notch. It is a peculiarity of Pöebrotherium and the Tylopoda generally that the humeral facet on the upper border of the sigmoid notch is confluent with the facets on the lower border only along the inner side. This typical tylopod condition is characteristic of the species *S. gracilis*† and *S. crassipes* also. On the distal end of the radius there are three facets for articulation with the carpal bones, that for the scaphoid being the largest and rectangular in outline; that for the lunate being narrow and

FIG. 16.

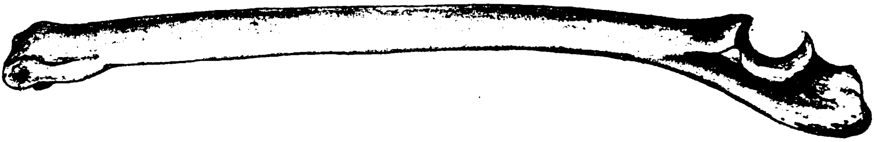

FIG. 16. *Stenomylus hitchcocki*, fused radius and ulna outer aspect. × 1/2.

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* This groove is characteristic of Pöebrotherium and Oxydactylus but not found in modern Tylopoda. Peterson does not find the groove in *S. gracilis*. Ann. Carnegie Museum, vol. iv, p. 292.

† Last cit. p. 455.

obliquely placed; while that for the cuneiform is triangular in outline and about half of it carried on the lower end of the ulna.

The carpus is compact and relatively high, the upper row of bones being the scaphoid, lunate and cuneiform as is typical for Tylopoda, their only peculiarity being that the lunate is relatively high and narrow. In the distal row the unciform is considerably deeper than the magnum; magnum and trapezoid are distinct, as is characteristic of tylopods; and the trapezium is represented by a tiny ossicle found also in Pöebrotherium. The pisiform is light and slender in its outlines.

FIG. 17.

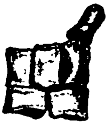

FIG. 17. *Stenomylus hitchcocki*, carpus from the anterior side. × 1/2.

The metacarpus consists of the functional digits III and IV, together with tiny nodules representing the upper ends of digits II and V. Metacarpus II is a nodule some 10^{mm} in length, occupies a pit on the outer side of the third metacarpal, and carries two tiny artificial facets, one for the trapezium, the other for the trapezoid. Metacarpals III and IV are relatively long, almost equaling the humerus in this dimension, and separate from each other throughout their entire length. Along the upper two-thirds they are closely appressed and flattened, but through the distal third they spread apart and each metacarpal bone has a circular cross section. At the proximal end metacarpal III rises slightly above mc. IV and has on the end a larger facet for the magnum and a smaller one for the trapezoid, behind which is a tiny facet for the trapezium, while on the lateral border there is a smoothed surface for the vestigial mc. II. The proximal end of the fourth metacarpal has almost the entire upper surface given up to a large facet for the unciform, only a small spur rising behind and presenting facets to the magnum and trapezoid. On the ulna side there is a small excavation for a tiny nodule some 5–7^{mm} long and representing the fifth metacarpal. The distal ends of the third and fourth metacarpals carry the enlarged trochlea for the phalanges,

FIG. 18.

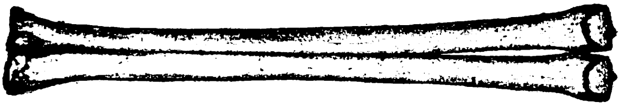

FIG. 18. *Stenomylus hitchcocki*, metacarpus from the anterior side. × 1/2.

each with a high carina, which is, however, confined to the plantar side.

The two first phalanges are long and slender, with the distal ends expanded in true tylopod manner. The upper articular surface is a shallow concavity, a notch in the lower margin being the only indication of the carina of the metapodial. The distal phalanges are a trifle over half the length of the proximal ones, and like them are considerably expanded, though not to the extent found in modern camels. The upper articular face is a shallow groove, while that on the lower end extends from on the upper clear around on to the plantar surface. The ungual phalanges are high, long pointed, rounded on the outer side and nearly vertical on the inner face. They are typical for a distinctly digitigrade artiodactyl.

Fig. 19.

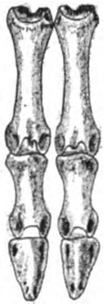

Fig. 19. *Stenomylus hitchcocki*, phalanges from the upper side. × 1/2.

The following figures give the measurements for the various front limb bones in the three known species:

	Scapula			Humerus			Ulnar-radius*		Metacarpus		Phalanges		
	length	width	width of fossa	length	diameter of head	diameter of trochlea	length	thickness	length	thickness	length 1	2	3
S. hitchcocki	138	78	22	168	26	27·5	225(191)	10·5	158·5	11·25	35	20	17
S. crassipes				194	32	28·57	229(194)	13	166	13 5	41		
S. gracilis				195	37	33	254(225)		184		44		

Fig. 20.

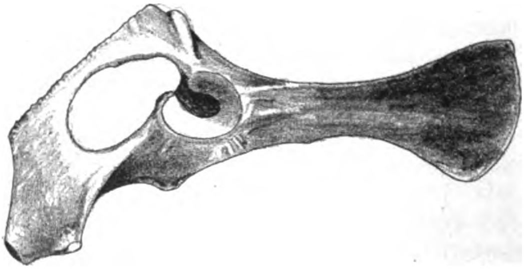

Fig. 20. *Stenomylus hitchcocki*, os innominatum seen from the lateral aspect. × 1/2.

Hind limb.—While in general the innominate bone is of the tylopod type, it is longer and relatively less expanded, especially in the iliac region. The upper end of the ilium is widely expanded and has a large area for the attachment on the sacrum. The neck of peduncle is longer and slenderer than usual. In the neighborhood of the acetabulum this bone is marked by several transverse ridges for the attachment of muscles quite as in the modern camels. The ischium is stout and expanded behind, a high slender process with its tuberosity rising on the superior ridge, and a second, the ischial tuberosity, being well developed at the posterior angle. The pubis is short and stocky, being expanded along the wide symphysis until it meets the ischium. In general conformity to the elongation of the pelvis the thyroid foramen is oval. The acetabulum is deep with a wide notch below.

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* In parenthesis is given the length of the radius.

The short femur has a marked curvature, being generally tylopod in character. Its head is small and rounded, with the pit for the round ligament well to the posterior side. The bridge between the head and the greater trochanter is both short and high, as is common to the camels generally; and the greater trochanter rises high above it, making a wide notch, as is also found in Pöebrotherium. The bridge is compressed antero-posteriorly, so that the digital fossa makes a deep pit, the bottom of which is about on a level with the lesser trochanter. This latter is situated high on the shaft, and from it runs a long ridge for muscular attachments. The rotular trochlea is broad and shallow and does not extend far up on the shaft. The external condyle is larger than the inner, which stands obliquely to the transverse axis of the shaft.

FIG. 21.

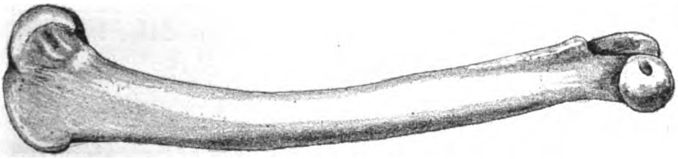

FIG. 21*a*.

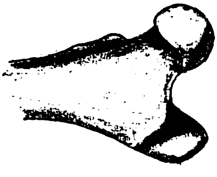

FIG. 21. *Stenomylus hitchcocki*, femur seen from the inner side. × 1/2.
FIG. 21*a*. Head of femur from the posterior side.

The patella is broadly oval and simple in outline, having nothing of the prolonged process common to later Tylopoda.

FIG. 22.

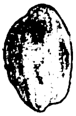

FIG. 22. Patella. ×1/2.

The slender tibia is about a fourth longer than the humerus, which, when compared with other tylopoda, is not long. The facets for the femoral condyles are wide and nearly flat, being separated by a bifid tubercle. The cnemidial crest is extremely prominent, and extends about a third of the way down the bone. In the regions of the crest the cross section is triangular, but below the section is transversely oval. The distal end of the bone is expanded and the inner astragular facet much wider and shallower than the outer, the two being separated by a prominent septum. Both these facets and that on the septum are interrupted in the middle by a shallow depression, which extends from near the inner margin of the inner facet all but to the outer margin of the outer facet. This is a very marked characteristic of the modern camels, and begins as far back as in Pöebrotherium at least. The fibular facet is divided by the groove for the fibula shaft into anterior and posterior portions.

The proximal end of the fibula is reduced to a tiny spine fused to the fibula; the distal end to a nodular bone wedged in between the tibia and the calcaneum. It presents a tiny spur above, vestige of the original shaft, which fits into the groove on the tibia; and has a long continuous facet for articulation on the tibia. On the inner surface is a crescentic grooved facet for the astragulus, and on the lower surface a concave face for the calcaneum.

FIG. 23.

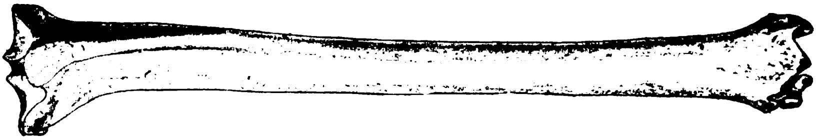

FIG. 23. *Stenomylus hitchcocki*, tibia and fibula from the anterior side. ×1/2.

In conformity to the slender build the tarsus is narrow and high. The astragulus is narrow, with the external condyle somewhat higher than the internal. On the distal trochlea the facet for the cuboid is relatively narrow, while that for the navicular is proportionally wide. The plantar facet is comparatively narrow and small. In general, however, the astragulus would be recognized as tylopod. The calcaneum is of moderate length, being distinguished only by the considerable antero-posterior diameter of its shaft, this depth being especially great near the facet for articulation on the cuboid. The cuboid is compressed transversely, developed in the antero-posterior diameter, and carries a heavy plantar hook in the rear. The navicular is moderately developed, having a large concave face for the astragulus, which facet is notched on the inner margin. The lower side has a large facet for the ecto-meso-cuneiform and a smaller one for the ento-cuneiform, beside the lateral articulations where it rubs against the cuboid. The ecto-meso-cuneiform is free from the navicular, rectangular in form, and carries a single facet above for the navicular, a second below for the third metatarsal, and a third laterally for the ento-cuneiform. This last bone is a small nodule, with facets for the navicular, the ecto-meso-cuneiform and for the plantar process of the cuboid.

FIG. 24.

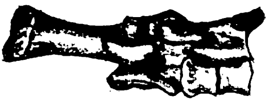

FIG. 24. *Stenomylus hitchcocki*, tarsus. × 1/2.

FIG. 25.

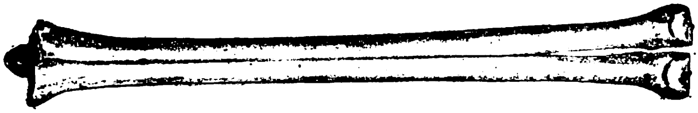

FIG. 25. *Stenomylus hitchcocki*, metatarsus from the anterior side. × 1/2.

FIG. 26

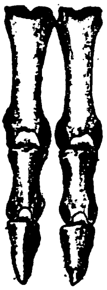

FIG. 26. *Stenomylus hitchcocki*, phalanges of the hind foot, from the upper side. × 1/2.

The metacarpus consists of the functional digits III and IV, fused for a little more than the upper half of their length, a tiny nodule representing mt. II, and a still smaller nodule representing mt. V. In length the metatarsus is a trifle longer than the metacarpus. The vestige of the second metatarsal is 8^{mm} long by 6^{mm} wide and carries a tiny facet for articulation on the ento-cuneiform. The vestige of mt. V is but 3^{mm} long and 5^{mm} wide and has no facets. The upper end of the third metatarsal is occupied by the facet for the ecto-meso-cuneiform, that of mt. IV by the facet for the cuboid; then each contributes a strong process from the plantar side, on the inner side of which is a facet for the ento-cuneiform. The distal ends of the two metapodials spread in a characteristic manner and each carries a broad trochlea for phalangeal articulation, and on each of these there is a prominent carina, which, however, is confined to the lower side and is not as prominent as the corresponding ones on the front metacarpals.

The proximal phalanges are a trifle shorter than those of the front foot, but otherwise similar in form. The distal and ungual phalanges are also very like those of the front foot.

The following figures give the comparative measurements of the three species of Stenomylus.

	Femur			Tibia		Metatarsus		Phalanges		
	length	diameter of head	diameter of trochlea	length	diameter of upper end	length	thickness	1	2	3
S. hitchcocki	176	18	31	210	32·5	166	11	36	20	17
S. gracilis	205	19	34	248	38	198		44		
S. crassipes	212	20	38·5	213	39	185	12·5			

Classification.

Stenomylus Peterson

Ann. Carnegie Museum, vol. iv, 1906, p. 41.
" " " vol. iv, 1908, p. 286.

The type species is *S. gracilis*, found by Peterson in the Lower Harrison beds of Sioux Co., Neb. The genus may be defined as follows: Stenomylus is a slender member of the Tylopoda, adapted to an upland life, with an extreme hypsodont dentition of $i.\frac{3}{3}c.\frac{1}{1}p.\frac{4}{4}m.\frac{3}{3}=\frac{22}{22}=44$; the upper canines partly and the lower canines wholly incisiform, the first lower premolar tending the same way; vertebral formula c.7d.12-l.7c.14; an elongated neck; limbs didactyl and digitigrade; magnum and trapezoid free; and navicular and ecto-mesocuneiform free. Horizon, Lower Harrison.

At present three species are distinguished as follows:

Stenomylus gracilis Peterson

Ann. Carnegie Museum, vol. iv, 1906, p. 41.
" " " vol. iv, 1908, p. 286.

Distinguished by larger size, narrower upper molars, lower canine less incisiform, diastema between lower premolar 1 and 2 shorter, lower jaw narrower, metacarpals coössified a part of their length, and in details the most specialized of the three species.

Stenomylus hitchcocki sp. nov.

See preceding description of osteology for details. The species is distinguished by its small size, relatively narrow molars, lower canine completely caniniform, diastema between lower premolar 1 and 2 relatively long, premolar 2 greatly reduced, lower jaw deep, metacarpals separate their entire length. In general the species is the least specialized of the three.

Stenomylus crassipes sp. nov.

The species is distinguished in that while the size of the skull is approximately that of *S. gracilis*, the neck and limbs are markedly shorter and heavier; the premolars are much more reduced; and the lower canine is completely incisiform.

To this the following details may be added as a description of the species. The type is number 2150 in the Amherst College collection, and was found seven miles northeast of Agate, Sioux Co., Neb., in the uppermost sandstones of the Lower Harrison beds. The type consists of the skull (lacking premaxillæ) and lower jaws, together with 6 cervical, and 3 dorsal vertebræ, scapula, humerus, ulno-radius, carpals, metacarpals, and phalanges. With this has been used specimen 14220 of the American Museum of Natural History, consisting

FIG. 27.

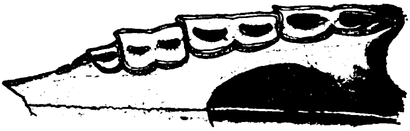

FIG. 27. *Stenomylus crassipes*, upper dentition and palate. × 1/2.

FIG. 28.

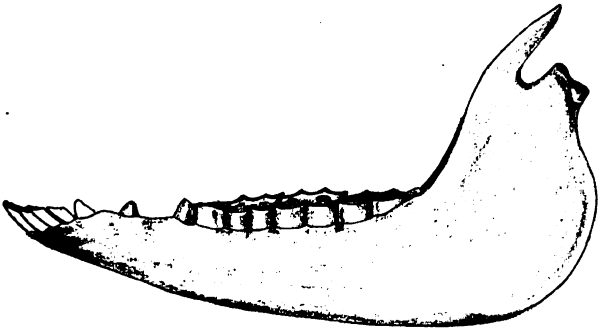

FIG. 28. *Stenomylus crassipes*, mandible and lower dentition for the outer side. × 1/2.

of nearly all parts of the skeleton; but the find is composed of the bones of more than one individual.

As is characteristic of the skeleton, the skull is heavily built, the cranial region being short, and the frontals wide. The premaxillæ and premolar regions are shortened over the corresponding regions of *S. gracilis*, but the back of the skull is about the same size. In dentition the upper incisors are the usual well-developed chisel-shaped teeth crowded together; the canine is reduced and separated from the incisors by a diastema of 4^{mm}, being a like distance from the tiny first premolar. The second premolar is also much reduced, as is the third and the fourth, this last being 2^{mm} shorter than its counterpart in *S. gracilis*. The molars, however, are relatively enlarged, corresponding in length and width with those of *S. gracilis*. The lower jaw is shortened in the regions in front of the molars, the lower canine being wholly incisiform, as is also the first premolar which is placed close to the canine, all five of these teeth being grouped in the incisor aggregation. The second premolar has a considerable diastema, both in front and behind it, both being, however, shorter than those of *S. gracilis*. The third and fourth premolars are also reduced, and the molars are enlarged corresponding to those in the upper jaw.

Fig. 29.

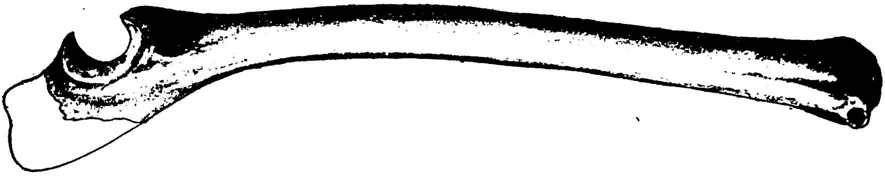

Fig. 29. ***Stenomylus crassipes*, fused radius and ulna from the outer aspect.** × 1/2.

The cervical vertebræ resemble those of *S. hitchcocki* in character, but are thicker and shorter than in that of the *S. gracilis* species. From the table of measurements it will appear that the humerus is about the same length as that of *S. gracilis*, but the ulno-radius is some 30^{mm} shorter and at the same time much stockier. In the same way the metacarpus is materially shorter and heavier, mt. III and mt. IV being fused together for about half their length as in *S. gracilis*. The femur is relatively long, actually longer than that of *S. gracilis*, but as in the fore limb the tibia is extremely short, 35^{mm} shorter than that of *S. gracilis*. The metatarsus is also short and stocky, mt.

	Hypisodus	Stenomylus	Pöebrotherium
1	$i\frac{3}{3}c.\frac{1}{1}p.\frac{4}{4}m.\frac{3}{3}$	$i\frac{3}{3}c.\frac{1}{1}p.\frac{4}{4}m.\frac{3}{3}$	$i\frac{3}{3}c\frac{1}{1}p\frac{4}{4}m\frac{3}{3}$.
2	Dentition hypsodont	Dentition extremely hypsodont	Dentition brachydont.
3	Upper canine subincisiform	Upper canine subincisiform	Upper canine caniniform.
4	Lower canine incisiform	Lower canine incisiform	Lower canine caniniform.
5	Lower premolar 1 incisiform	Lower premolar 1 subincisiform	Premolar 1 normal.
6	Bulla large, hollow, fused to paroccipital process	Bulla large filled with canceolated tissue, fused to paroccipital process	Bulla large filled with canceolated bone, fused to paroccipital process.
7		Hard palate ends opposite front of second molar	Hard palate ends opposite back part of second molar.
8		Vertebral formula c.7d.12l.7s.4c.14.	Formula c.7d.12l.7s.4c.14.
9		Vertebrarterial canal passes through the pedicle of the neural arch	Vertebrarterial canal passes through pedicle of neural arch.
10		Cervical vertebræ elongated, neural spines on 2-6 vestigial	Cervical vertebræ elongated, neural spines on 2-6 greatly reduced.
11	Magnum and trapezoid fused	Magnum and trapezoid free	Magnum and trapezoid free.
12		Ulna facets on upper border of sigmoid notch interrupted on outer or both sides	Ulnar facets interrupted along the outer side.
13	4 functional digits on fore limb, upper and lower ends of mc. retained	2 functional digits retained on fore limb, upper ends only of vestigial digits retained	2 functional digits retained on fore limb, upper ends only of vestigial digits retained.
14	Navicular and cuboid fused	Navicular and cuboid free	Navicular and cuboid free.
15		Distal tibial facets interrupted	Distal tibial facets interrupted.
16	2 functional digits on hind foot, lateral mt. retain both upper and lower ends and digits	2 functional digits on hind foot, lateral mt. lose lower ends and digits	2 functional digits retained on hind foot. Lateral digits lose lower ends and digits.

III and mt. IV being fused rather more than half their length. From the foregoing it will appear that *S. crassipes* is a species closely resembling *S. gracilis*, but differentiated by the shortening of the limbs, especially below the elbow and knee, a heavier shorter-limbed type being thus evolved.

Affinities.—In his descriptions Peterson has placed the genus Stenomylus among the Tylopoda, near the long-limbed type Oxydactylus; while Matthew* has associated the genus with Hypisodus among the Hypertragulidæ. In order to show concisely the points of likeness and difference to one or the other of these types, the characters of Stenomylus are in the above diagram arranged in parallel columns with those of Hypisodus on the one side and with Pöebrotherium on the other, the latter being used as illustrating a primitive tylopod.

FIG. 30.

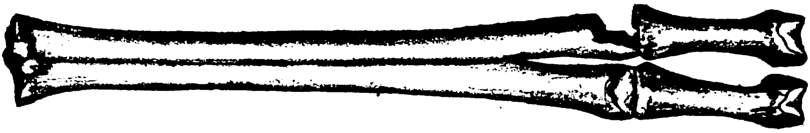

FIG. 30. *Stenomylus crassipes*, metatarsus and proximal phalanges. × 1/2.

From the foregoing table it is evident that in the matter of dentition (number 1-5) the genus Stenomylus approximates Hypisodus; but in the other skeletal features it is distinctly allied to the Tylopoda. This is especially marked in such deep-seated and fundamental characters as the cancellous bone in the bulla, the position of the vertebrarterial canal, the matter of the fusion of the magnum and trapezoid, the matter of fusion of the navicular and cuboid, and the manner in which the lateral digits have been reduced. These are characters less liable to modification on a change of habit, while the dentition is the first to respond to changes in the matter of food. I feel therefore that Stenomylus should be placed among the Tylopoda. Then as it is evident that the dentition is aberrant in its extreme hypsodont specialization, and presuming that this characteristic has been acquired in conjunction with a special feeding habit (which feeding habit would presumably be the same as characterizes Hypisodus, but a parallel adaptation), I feel that Stenomylus should be set off by itself. The habit, which is general to forms having this hypsodont dentition, is feeding on hard grasses, usually on the open prairies, the grass having in its stem considerable quantities of silica which causes extremely rapid wear of the teeth. I take it then that while the typical tylopod contemporaries of the Protomeryx type, fed on a generalized diet, and retained their brachydont dentition, and while the long-limbed Oxydactylus group were feeding on leaves and shrubbery, and likewise retained their brachydont dentition, that there arose another group of upland tylopods which took up the grazing habit, and these developed the hypsodont dentition. These then represent a separate branch of the Tylopoda, which must have had its beginning in the later part of the Oligocene, being derived from Pöebrotherium, which genus Stenomylus resembles in most of its characters. This group of tylopods seems to have flourished greatly during the lower Miocene, especially during the Lower Harrison, outside of which horizon it has not been found. I see no especial affinity to Oxydactylus other than that common to all Tylopoda. The affinities may be graphically indicated as follows:

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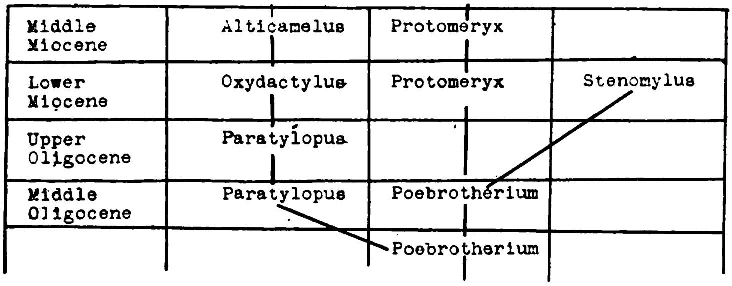
* Bull. Amer. Museum Nat. Hist., xxiv, 1908, p. 539.



The Lower Harrison beds then will show three types of Tylopoda, each presumably in a different type of habitat, the Stenomylus in the upland, the Protomeryx near or in the valleys where a considerable variety of vegetation flourished, and the Oxydactylus in the intermediate country and probably feeding on leaves and twigs of trees.

Collectors in the Lower and Upper Harrison beds can not but be greatly impressed by the great variety of tylopods which occur in these beds, there being beside the already known species certainly as many more indicated by the great variety of toe and isolated bones found. The Lower Miocene seems to be the period of especial luxuriant development for all types of camel-like forms.

Amherst College.

ART. XXV.—*The Refractive Index of Canada Balsam*; by WALDEMAR T. SCHALLER.

THE refractive index of Canada balsam, as it occurs in the thin sections made for the U. S. Geological Survey, was determined on the request of Mr. F. C. Calkins, who had found* that the index, or n, was not absolutely constant but varied between two extremes. By the examination of 300 slides, he found n to reach and even slightly exceed ω of quartz (1·544), though n was found greater than 1·544 only in the proportion of one slide in a hundred. The excess was very small and the balsam was decidedly yellow. The lowest value found by him was about 1·535 ± ·002.

The value of n for sodium light was determined on an Abbe-Zeiss refractometer by total reflection on three kinds of slides, which were (1) not cooked as much as usual, (2) cooked as ordinarily done, and (3) over-cooked. The differences found between (1) and (2) are very slight, and, in fact, the individual values show almost as much variation as between the different groups. The values obtained are:

$$\begin{array}{ccc} (1) & (2) & (3) \\ n = \left\{ \begin{array}{l} 1{\cdot}539 \\ 1{\cdot}538 \\ 1{\cdot}539 \end{array} \right. & n = \left\{ \begin{array}{l} 1{\cdot}536 \\ 1{\cdot}538 \\ 1{\cdot}539 \end{array} \right. & n = \left\{ \begin{array}{l} 1{\cdot}543 \\ 1{\cdot}540 \\ 1{\cdot}540 \\ 1{\cdot}542 \\ 1{\cdot}541 \end{array} \right. \end{array}$$

The average values are for (1), 1·5387: for (2), 1·5377; for (3), 1·5412, or, as the average of all, 1·5395, which is almost identical with the value (1·5393) given by Becker† in 1898. A determination of n in a slide six years old gave the value 1·5390. These values show that, in general, n lies very close to 1·539 and that this value may well be used in a study of a thin section, while the actual possible variation was found by Mr. Calkins to be from 1·535 to 1·545, though the extreme values are but seldom reached. The uncooked, liquid balsam has a refractive index of 1·524, which, after cooking, rises to 1·54. The older a slide, the higher the index of the balsam becomes, which after a time, especially if the air has access, reaches towards the highest value, or 1·545.

Chemical Laboratory, U. S. Geological Survey.

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[*] Science, vol. xxx, p. 973, Dec. 31, 1909.

[†] This Journal [4], v, p. 349.

Art. XXVI.—*Stratigraphy of the upper Carboniferous in West Texas and Southeast New Mexico;* by G. B. Richardson.*

Introduction.

In the trans-Pecos portion of Texas and New Mexico, everywhere that basal strata of upper Carboniferous age have been observed they lie unconformably on older Paleozoic strata or on pre-Cambrian rocks. This unconformity marks one of the important time breaks in the geological history of the southwest. The upper Carboniferous rocks consist of limestone, shale, sandstone, and variegated red beds. Limestone, with locally a basal conglomerate, usually forms the lower part of the section, and the uppermost strata are red beds which are unconformably overlain by deposits of Triassic age. The sequence, however, is extremely varied. The lowest rocks are Pennsylvanian and the uppermost are Permian, but where to draw the dividing line between Pennsylvanian and Permian in this region is an open paleontological question. These rocks comprise a maximum of more than 15,000 feet and thus constitute one of the thickest upper Carboniferous sections known.

In connection with work in the Van Horn quadrangle in west Texas, it became desirable to examine the northward continuation of the rocks there exposed, and last summer (1909) I had the opportunity to make a short trip to the Guadalupe and Sacramento mountains and adjacent portions of New Mexico. The result enables a comparison of several upper Carboniferous sections in the little-known area between the Rio Grande and Pecos River. In the following descriptive sections I have summarized the results of my own work of the past several seasons, and for comparison I have referred to the work of J. A. Udden in the Chinati Mountains and of C. H. Gordon and Willis T. Lee in Rio Grande Valley. I gratefully acknowledge my obligations to Dr. Girty, who has accompanied me on several trips into the field and has examined all of my collections of fossils.

Section in Chinati Mountains, Texas (No. 1, figs. 1 and 2).—J. A. Udden† in 1904 reported the presence of some 6,000 feet of upper Carboniferous rocks in the Chinati Mountains, about 175 miles southeast of El Paso. These consist of conglomerate, sandstone, shale, and limestone, which he separated into three formations called the Cibola beds, the Alta beds, and the Cieneguita beds, and named the whole the Chinati series. These rocks are delimited below by intrusive granite and are unconformably overlain by Lower Cretaceous strata. The fossils obtained from Udden's Chinati "series," Dr. Girty informs me, are more suggestive of the Hueco fauna than of the typical Guadalupian. Recently Stuart Weller,* in describing some crinoids from the Cibola beds, has referred to them as Permian. Correlation by stratigraphic tracing is precluded by the isolated occurrence of the rocks in the Chinati Moun-

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* Published by permission of the Director of the U. S. Geological Survey.

† Udden, J. A., The Geology of the Shafter Silver Mine District: Bull. University of Texas Mineral Survey No. 8, 1904, pp. 11-25.

FIG. 1.

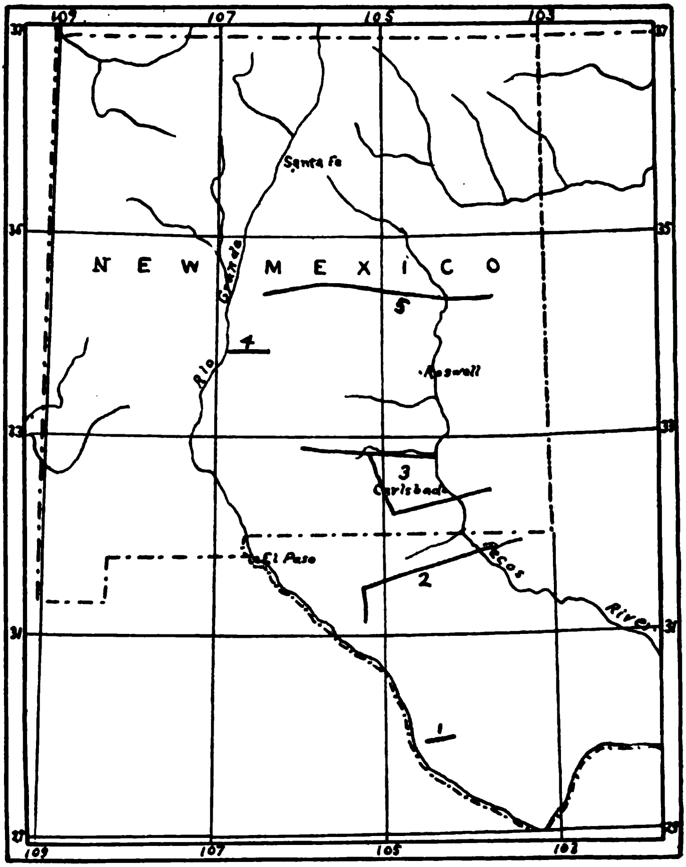

FIG. 1. Map of New Mexico and west Texas showing location of sections.

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* Journal of Geology, vol. xvii, pp. 623–635, 1909.

FIG 2.

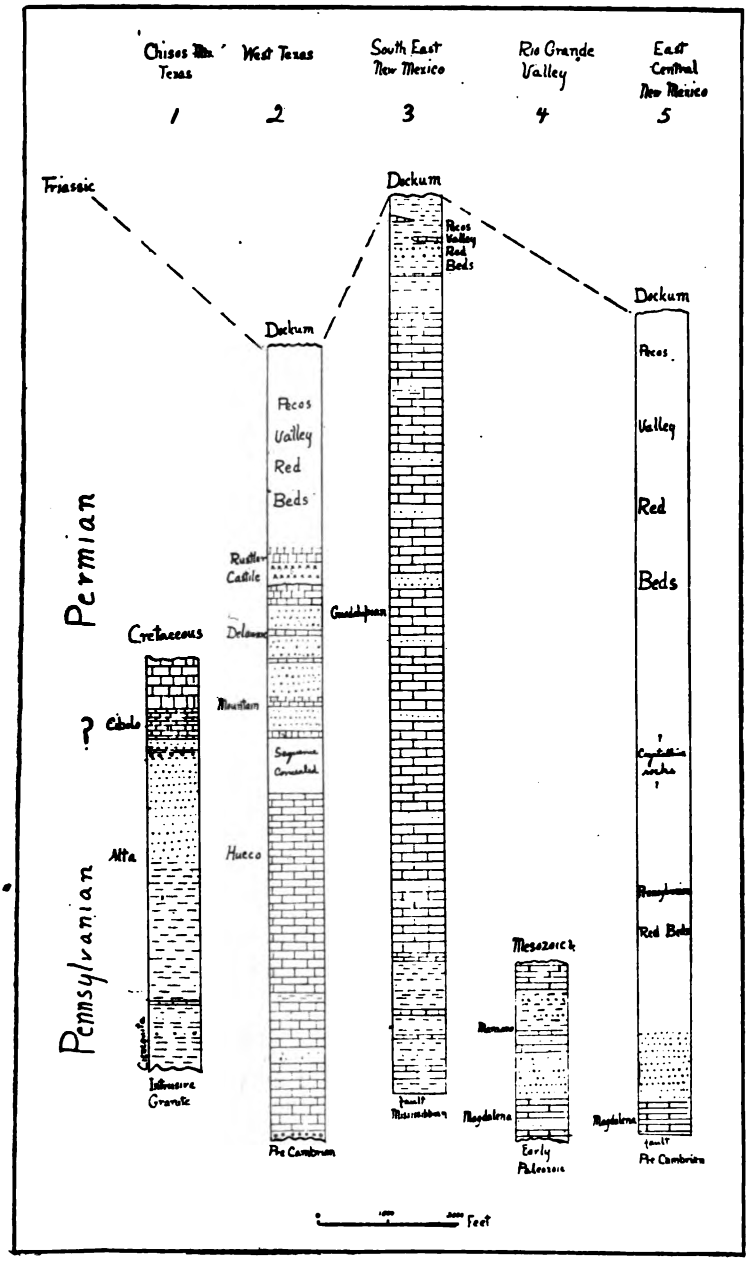

FIG. 2. Generalized columnar sections of upper Carboniferous strata in southeast New Mexico and west Texas.

tains, they being more than 50 miles distant from the nearest known Carboniferous outcrops farther north, in the vicinity of the Texas and Pacific Railway, where what are presumably equivalent beds are all limestone. The section in the Chinati Mountains compared with those described below illustrates the variability of the upper Carboniferous deposits in the area under consideration.

Section in Rio Grande Valley, New Mexico (No. 4, figs. 1 and 2).—Rocks of Carboniferous age have long been known to occur in the ranges on both sides of the Rio Grande in New Mexico, although the section there exposed is not nearly as complete as farther east. Gordon, Lee and Girty* have recently summarized the knowledge of the upper Carboniferous in that region and they divide the rocks into the Magdalena and Manzano groups.

The Magdalena group, the older of the two, consists chiefly of limestone but it contains minor beds of shale and sandstone. Gordon states that in Socorro, Valencia, and Bernalillo counties the Magdalena group comprises 1,000 to 1,300 feet of sediments, which he divides into the Sandia formation (consisting of sandstone, shale, and limestone) and the overlying Madera limestone. In southern New Mexico the Magdalena group is chiefly limestone and its outcrop in the San Andreas Range, save for minor interruptions caused by intrusive igneous rocks and by deposits of unconsolidated Quaternary debris, can almost be traced into the Hueco limestone on the western flanks of the Franklin Range in Texas. Pennsylvanian fossils from the two limestones confirm this correlation. The Magdalena is separated from the overlying Manzano group by a local unconformity which is not persistent throughout southeast New Mexico and west Texas.

In the northern part of Rio Grande Valley the Magdalena group is overlain by a mass of red beds to which Herrick applied the name Manzano. Lee has recently revised the nomenclature and includes in the Manzano group the following three formations named, in ascending order: the Abo sandstone, consisting of a maximum thickness of 800 feet of coarse red to purple sandstone with subordinate shale and earthy limestone; the Yeso formation, consisting of 1,000 to 2,000 feet of alternating vari-colored strata of shale, friable sandstone, gypsum, and earthy limestone; and the San Andreas, a massive limestone of variable thickness which overlies the red beds in the southern part of the Rio Grande region. Farther north the San Andreas limestone becomes less prominent and finally disappears and the top of the Manzano group is marked by an erosional unconformity above which are strata of unknown age. Numerous fossils, which are described by Dr. Girty in the bulletin above referred to, have been found in the Manzano group, those occurring in the several formations being not radically different. They are referred to the Pennsylvanian and the Manzano group is correlated with part of the Hueco formation.

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*Gordon, C. H., Notes on the Pennsylvanian Formations in the Rio Grande Valley, New Mex., Jour., of Geology, vol. xv, 1907, pp. 805–816; Lee, Willis T., and Girty, Geo. H., The Manzano Group of the Rio Grande Valley, New Mex., Bull. U. S. Geol. Survey, No. 389, 1909.

Section in west Texas north of the Texas and Pacific Railway (No. 2, figs. 1 and 2).—One of the thickest sections of the upper Carboniferous in the area considered in this paper is exposed in Texas between the western escarpment of the Staked Plains and the Rio Grande. Although this section is not complete, being interrupted by faults and by a local unconformity, it is more than 10,000 feet thick.

The lower part of the section consists of the Hueco formation, which underlies an area of several hundred square miles and outcrops in the Hueco, Franklin, Finlay, Cornudas and Sacramento mountains and in the Sierra Diablo. It is in many areas mainly limestone but in other areas consists also of shale and sandstone, including red beds, and in places a basal conglomerate is well developed. A well recently sunk in the Hueco formation in the drift-covered area between the Sierra Diablo and the Cornudas mountains, about 40 miles north of Sierra Blanca, is reported to have encountered a thin deposit of red beds intercalated in the prevailing limestone. This is of interest in the correlations discussed below (p. 335). Exact measurements are difficult to obtain, but in Texas the Hueco formation is approximately 5,000 feet thick. Wherever exposed, the base of the Hueco lies unconformably on rocks ranging in age from pre-Cambrian to Silurian. Over wide areas the top of the formation has been eroded; locally the Hueco is overlain by Lower Cretaceous strata and relations to higher rocks in the Carboniferous section are completely concealed in Texas by the bolson plain known as Salt Flat.

The Hueco formation bears a rich Pennsylvanian fauna which Dr. Girty states is widely distributed over the Western States and which he provisionally correlates with the fauna of the Aubrey group in Arizona, etc.

The upper Carboniferous section is continued east of the Salt Flat bolson, in the Delaware and Guadalupe Mountains, by 4,000 feet of strata which contain Girty's* Guadalupian fauna. These rocks have been separated into the Delaware Mountain formation, consisting of 2,200 feet of variable beds of sandstone and limestone, and the overlying Capitan limestone, which is at least 1,800 feet thick. The stratigraphic position of these formations is not determinable in Texas, but their position in the upper Carboniferous section is shown in the northern part of the Guadalupe Mountains in New Mexico and will presently be referred to. On the eastern flanks of the Delaware Mountains, which constitute virtually a dip slope, the Capitan limestone is missing—presumably either because of non-deposition or erosion—and the Delaware Mountain formation is directly overlain by a mass of bedded gypsum. This deposit, named the Castile gypsum, is approximately 300 feet thick and covers an area of several hundred square miles. The gypsum is overlain by magnesian limestone and associated lenses of sandstone, in all about 200 feet thick, which have been named the Rustler formation. The section is here interrupted by Quaternary deposits in Pecos Valley, but occasional outcrops of red beds, which overlie the Rustler formation, are locally exposed and it is evident that both the Castile gypsum and the Rustler formation are members of the red bed complex that underlies the valley of Pecos River.

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*Girty, George H., The Guadalupian Fauna: Prof. Paper U. S. Geol. Survey, No. 58, 1908.

Red Beds of Pecos Valley.

The red beds of Pecos Valley were examined in 1891 by W. F. Cummins,* and they have been studied in the vicinity of Roswell by C. A. Fisher,† but thick deposits of unconsolidated Quaternary debris conceal complete exposures and comparatively little is known of them. They consist of a group of vari-colored sandstone and shale, red predominating, interstratified with beds of magnesian limestone and gypsum. In detailed study it is desirable to divide these rocks into a number of formations of comparatively limited extent similar to the Castile gypsum and the Rustler formation, which when traced for a number of miles beyond the area in which they were named, lose their individual character and become difficult to recognize as such. The formations of the red bed group are lenticular in character but the group as a whole is a distinct unit.

Measurements of thickness are practically impossible to obtain short of drilling, and as yet no hole has been sunk through the entire group. Minimum figures, however, are afforded by two deep wells; one, sunk by Capt. John Pope in 1855–57, about ten miles east of where Delaware Creek enters Pecos River in New Mexico near the Texas boundary, was 1,050 feet deep and appears to have been in red beds all the way;* another was sunk by H. J. Hagerman in 1909 about 20 miles east of Roswell, New Mexico, in section 5, T. 11 S., R. 28 E., to a depth of 2,850 feet. Apparently this well was begun near the top of the local section of red beds and was continued in them to a depth of 1,625 feet, beneath which limestone, including some thin sandy layers, was encountered down to the bottom of the well. A minimum thickness therefore of these red beds is 1,600 feet.

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* Cummins, W. F., Notes on the Geology West of the Plains: Third Ann. Rept. Geol. Survey of Texas, 1892, pp. 201–218.

† Fisher, C. A., Geology and Underground Waters of the Roswell Artesian Area, New Mexico: Water Supply Paper U. S. Geol. Survey, No. 158, 1906.

The red beds of Pecos Valley are delimited above, as Cummins and Drake† determined a number of years ago, by an erosional unconformity which separates them from the overlying Dockum formation of Triassic age.

The lower limit of the red beds of Pecos Valley, defined as the lowest occurrence of either red strata or of gypsum, is variable and is not a definite horizon, but rather forms a zigzag line extending diagonally across the strike of the rocks. In Texas the basal formation of the red bed group, the Castile gypsum, rests directly on the Delaware Mountain formation. Farther north in New Mexico, southwest of Carlsbad, the red beds rest on strata which are a few thousand feet above the Capitan limestone but which are conformable with it.‡ On the eastern flanks of the Guadalupe Mountains west of Carlsbad red beds occur at a somewhat lower horizon interbedded with these strata which lie above the Capitan limestone. Local exposures clearly show the "fingering out" of red beds and their merging into the more sombre-colored deposits, the occurrence of the red coloration extending across the strike of the rocks. West of Roswell the main red beds lie upon a massive limestone which is the northern continuation of the rocks that have just been referred to. Deposits of red sandstone and shale are also intercalated in the limestone west of Roswell. Farther north, along the line of the Eastern Railway of New Mexico, as shown below, almost the entire Carboniferous section is composed of red beds.

Fossils are of rare occurence in these red rocks, although at a few localities shells have been obtained from the interbedded limestones, and fragments of fossil wood also have been found. Dr. Girty does not feel justified in saying anything definite as to the age of the fossils collected from the red beds either by Mr. Fisher or by myself. These include *Schizodus ovatus* and *Pleurophorus aff. subcostatus* from seven miles northwest of Roswell, New Mexico, and a *Schizodus* having the general shape of *S. harei*, and a form suggesting by its shape a small *Myalina* from the Rustler Hills, El Paso County, Texas. Nevertheless the stratigraphy indicates that the red beds of the Pecos Valley are to be correlated with part of the Permian red beds of Oklahoma and northwest Texas, for they were connected by tracing around the northern border of the Staked Plains by W. F. Cummins in 1891; and on my map of trans-Pecos Texas, published in 1904, the Castile gypsum and Rustler limestone were referred to the Permian with a query. Cummins' work has been confirmed by C. N. Gould, who has mapped the Greer and Quartermaster formations, which are part of the Permian red beds of Texas and Oklahoma, across several counties in the panhandle of Texas, and along Canadian River as far as the Texas–New Mexico boundary.*

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* Annual report of Capt. A. A. Humphreys to the Secretary of War, December, 1858.

† Drake, N. F., Stratigraphy of the Triassic Formation in Northwest Texas: Third Ann. Rept. Geol. Survey of Texas, 1892, pp. 227–235.

‡ When detailed work is done in this region these strata which lie above the Capitan limestone will be separated into formations and probably included in the same group with the Delaware Mountain formation and the Capitan limestone, but it is not desirable now to introduce new names.

This stratigraphic correlation is in agreement with paleontologic data recently obtained by Dr. J. W. Beede, with whom I was associated in the field for a few days in 1909 and who found fossils in a limestone in the red beds south of Lakewood, New Mexico, which he correlates with the Whitehorse–Quartermaster fauna. A discussion of this correlation, however, is outside the scope of the present paper, and is left to Dr. Beede.

Section across east central New Mexico (No. 5, figs. 1 and 2).—In 1905 I traversed the line of the Eastern Railway of New Mexico, then under construction, and made the following observations between the Manzano Range and Pecos River.

This region, considered as a whole, is an undulating plateau 125 miles wide. On the west the plateau is separated from Rio Grande Valley by the Manzano Range, and on the east the escarpment of the Staked Plains rises above Pecos Valley. The western portion of the plateau, averaging about 6,000 feet in elevation, is dissected by the north-south trending Estancia and Encino valleys and is surmounted by occasional isolated mesas, while the eastern portion slopes gradually to an elevation of 4,000 feet at Pecos River. The topography of this belt is in marked contrast to that of the mountainous area south of it in New Mexico and Texas, where other sections of upper Carboniferous rocks described in this paper are exposed, the difference in topography being largely due to the varying hardness of the rocks. This contrast further emphasizes the variability of the upper Carboniferous stratigraphy.

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* Gould, C. N., Geology and water resources of the eastern portion of the Panhandle of Texas: Water Supply Paper U. S. Geol. Survey, No. 154, 1906; and Geology and water resources of the western portion of the Panhandle of Texas: Water Supply Paper U. S. Geol. Survey, No. 191, 1907.

At the base of the Manzano Range the extreme western part of the plateau is underlaid by several feet of limestone (Magdalena ?) containing a Pennsylvanian fauna, allied to that of the Hueco formation, and above the limestone there is a great mass of red beds that outcrop as far as the vicinity of Lucy, a railroad station about 45 miles east of the Manzano Range. The rocks consist of prevailing fine-textured dark red sandstone with which are associated layers of red sandy shale and lenses of gypsum; and thin beds of limestone, containing numerous Pennsylvanian fossils, also occur towards the upper part of the section.

Five miles south of the town of Willard, at the crossing of the Santa Fe Central Railway, 25 miles east of the Manzano Range, the following section was measured:

Section Five Miles South of Willard, New Mexico.

	Feet.
Limestone, grey, cherty, fossiliferous	50
Sandstone, grey, friable	300
Sandstone, red	10
Gypsum, massive, bluish white	100

The fossils in the limestone are of Pennsylvanian age, so that the great mass of red beds lying between limestones containing Pennsylvanian fossils clearly are of that age. These beds belong to the Manzano group, but on account of the varied stratigraphy it cannot at present be stated that the limestone at the top of this local section is the San Andreas limestone, or one of several other lenses in the Manzano group.

The eastward continuation of the red beds is interrupted at the divide between Estancia and Encino valleys by an area of low relief, about ten miles wide, that is underlain by a crystalline complex consisting of granite and other igneous rocks, slate, etc., which apparently represent the southward continuation of the pre-Cambrian core of the Rocky Mountains. About fifteen miles southeast of this area, northeast of Torrance on the El Paso and Southwestern Railroad, isolated areas of mica schist surrounded by unconsolidated deposits were also found. The relations of these ancient rocks to the red beds is obscured by Quaternary material and is not known.

East of this crystalline area the character of the underlying rocks is much obscured by surface debris, but the general low eastward dip apparently prevails throughout the region. Lion Summit, just east of Encino Valley, is formed by about 50 feet of white sandstone capped by a bed of limestone in which no fossils were found. Thence eastward down the long, gentle slope of 60 miles to Pecos River there are few exposures of bed rock. The surface is generally covered by Quaternary debris, but a number of exposures show the presence of red beds and gypsum dipping low to the east, and records of deep wells indicate that all of this area is underlain by red beds. For instance, a well at Vaughan, a station at the crossing of the El Paso and Southwestern Railway near the western end of this long slope, is 1,355 feet deep in red beds all the way; and a well at Ricordo, 62 miles southeast of Vaughan along the railroad and thirteen miles west of Pecos River, shows red beds, below a superficial coating of sand, down to a depth of 595 feet. It appears then that red beds dipping eastward at a low angle underlie the entire area between Vaughan and Pecos River, and assuming a dip of only one degree a thickness of approximately 6,000 feet of strata is thus indicated. Practically the entire plateau, therefore, between the Manzano Range and Pecos River, with the exception of a small area of ancient crystalline rocks, is underlain by gently east dipping red beds which, unless they are duplicated by faulting, of which no evidence has been obtained, are more than 9,000 feet thick.

No fossils, excepting fragments of wood, have been found in the red beds between Willard and Pecos River. A thin section of a fragment of wood from the red beds one mile east of Pecos River, 65 miles north of Roswell, New Mexico, was reported on by David White as follows: This fragment "has lost many of its trachial punctations by reason of advanced bacterial action which has also obliterated many of the medullary rays. On the basis of the remaining ray features and the occasional obscure pores, I am disposed to regard this specimen as post-Pennsylvanian. These rocks are the northern continuation of the red beds of Pecos Valley described above, and here also they are unconformably overlain by the Dockum formation (Triassic), which in turn is succeeded by the Tertiary deposits of the Staked Plains.

The point to be emphasized about this section between the Manzano Range and Pecos Valley is that almost the entire history of upper Carboniferous sedimentation is a record of red bed deposition, which is in marked contrast with the corresponding record in southern New Mexico and Texas.

Section across southeast New Mexico between Tularosa Desert and the Staked Plains (No. 3, figs. 1 and 2).—The section in the Sacramento and Guadalupe Mountains in southeast New Mexico exposes a great thickness of rocks and reveals the stratigraphic position of the strata which contain Girty's Guadalupian fauna, the correlation of which has caused dispute.

East of Tularosa Desert, the local name of the bolson plain along which the El Paso and Southwestern Railroad extends between El Paso and Alamogordo, a zone of faulting marks the western foot of the Sacramento Mountains. Red beds, in fault contact with limestones of Mississippian age, form the local base of the upper Carboniferous section in this vicinity, These red beds constitute the western escarpment of the Sacramento Mountains, and are at least 2,000 feet thick, the section being obscured by faulting. They consist of a variegated group of prevailing red sandstone and shale, minor beds of buff sandstone and drab shale, and lenses of gray limestone. The red beds are overlain by a great mass of limestone and subordinate gray sandstone having a minimum thickness of 3,000 feet. These upper strata form the eastern slope of the Sacramento Mountains, which is thirty miles long, the strata dipping low to the east at an angle slightly greater than the inclination of the surface. Numerous fossils have been collected at various horizons from the limestone lenses in the red beds and from the overlying strata. Dr. Girty states they are all unmistakably Pennsylvanian and correlates them with the fauna of the Hueco formation. This correlation is strengthened by the partial tracing of the beds from the southeastern base of the Sacramento Mountains into limestones in the upper part of the Hueco formation exposed in Texas east of the Cornudas Mountains; and by the recent discovery of red beds in a well north of Sierra Blanca (p. 329). This latter occurrence appears to represent the southern wedging out of the mass of red beds exposed in the escarpment of the Sacramento Mountains.

The description of this section may here be interrupted to revert to the rocks of the Guadalupe Mountains, the northern end of which coalesces with the eastern base of the Sacramento Mountains. It will be recalled that the rocks of the Guadalupe Mountains at their southern termination in Texas, near the New Mexico boundary, consist of about 4,000 feet of sandstone and limestone which have been separated into the Delaware Mountain formation and the Capitan limestone, the relation of which to the Hueco limestone, in Texas, is concealed by the Quaternary deposits of the Salt Flat bolson. In the New Mexico portion of the Guadalupe Mountains a more complete section is exposed than in Texas, and there the Capitan limestone is overlain by a few thousand feet of limestone and sandstone as stated above (p. 331). Throughout this entire region, the general dip is eastward at a low angle. The stratigraphy is varied, and both the Delaware Mountain formation and the Capitan limestone lose their individuality when traced far along the strike. The massive Capitan limestone, for instance, locally gives way to or is replaced by thinner bedded limestone and intercalated beds of sandstone, so that it is difficult to distinguish the northward continuation of the formation from the overlying and underlying beds. Considered as a whole the rocks of the Guadalupe Mountains constitute a group which in detailed work will be separated into units similar to the Delaware Mountain formation and the Capitan limestone. A red bed phase is developed in the upper part of the Guadalupe Mountain section 25 miles southwest of Carlsbad, where, as stated above, deposits of red sandstone and shale are present in the prevailing limestone and gray sandstone. To the east the red sediments become more abundant, and in Pecos Valley the strata of the Guadalupe Mountains are overlain by the red beds of Pecos Valley.

Followed along the strike to the northern termination of the Guadalupe Mountains in the vicinity of Penasco River, a distance of fifty miles north of the Texas-New Mexico boundary, the Guadalupian series are found to overlie the limestones and sandstones, which have just been described, on the eastern flanks of the Sacramento Mountains. No evidence of any disturbance which would alter the apparent simple relations of the rocks was observed. The zone of faulting developed along the western base of the Guadalupe Mountains near the state boundary fades away northward, and is represented in Panasco Valley, if at all, by a belt of gently undulating dips. The strata of the Guadalupe Mountains, therefore, overlie the Hueco formation conformably, and in turn are overlain by the red beds of Pecos Valley into which they tend to merge.

Comparatively few fossils have been obtained from the rocks in the New Mexico portion of the Guadalupe Mountains, and these Dr. Girty states show but little relationship to the typical Guadalupian fauna from the Texas portion of the mountains.* It is not within the province of this paper to consider the Guadalupian fauna or its relation to others which is discussed by Dr. Girty. It seems probable, however, that the difference in the fauna in the same group of rocks in the Texas and the New Mexican portions of the Guadalupe Mountains is due to changed environment, which is indicated by the varied stratigraphy.

Summary.

The following is a summary of the chief facts, which I wish to emphasize in this review of the upper Carboniferous stratigraphy of southeast New Mexico and west Texas:

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* Girty, George H., The Guadalupian Fauna and New Stratigraphic Evidence: Annals N. Y. Acad. of Sciences, vol. xix, pp. 135-147, 1909.

The upper Carboniferous strata in the area considered are separated from underlying and overlying rocks by major erosional unconformities. The lower beds are Pennsylvanian and the upper beds are Permian, but the separation of the two series is not well marked.

The total thickness is enormous, the stratigraphy is extremely varied, and two local unconformities occur in the upper Carboniferous section. In the east central New Mexico section, excepting a relatively thin deposit of limestone at the base of the section, almost the entire upper Carboniferous record is of red bed deposition. In southeast New Mexico a great body of sandstone and limestone occurs between and merges into red beds. In west Texas, north of the Texas and Pacific Railway, red beds are practically confined to the top of the upper Carboniferous section, and in the Chinati Mountain region no red beds have been reported.

The sections which have been described can be approximately correlated and together they comprise the local complete upper Carboniferous column. It appears: (*a*) that the Hueco formation embraces both the Magdalena and Manzano groups of the Rio Grande Valley section in New Mexico; (*b*) that the Guadalupian series lies between the Hueco formation and the red beds of Pecos Valley; (*c*) that the red beds of Pecos Valley constitute a variable group, the base of which is not a definite horizon, the occurrence of the red color extending irregularly across the strike of the rocks; (*d*) and that the upper part of the red beds of Pecos Valley is equivalent to the upper part of the Permian red beds of northwest Texas and Oklahoma.

The varied stratigraphy is an expression of changing geographic conditions which accompanied the emergence of the continent at the close of Paleozoic time. Apparently an open sea gave way, with some alterations, to shallower water and to local enclosed basins. The Guadalupian fauna probably migrated from the south, and its spread northward and eastward seems to have been checked by changing environment. It is to be noted that while from Kansas to Oklahoma shales and limestones merge into red beds from north to south, in west Texas and New Mexico a similar transition occurs from south to north, indicating an east-west zone in the upper Carboniferous area of deposition in which red beds accumulated.

Art. XXVII.—*The Gravimetric Determination of Free Bromine and Chlorine, Combined Iodine, and Oxidizing Reagents by means of Metallic Silver*; by Claude C. Perkins.

[Contributions from the Kent Chemical Laboratory, Yale Univ.—ccix.]

In a former paper* a method for the gravimetric determination of free iodine by means of metallic silver was described in detail. This paper has to do with the application of the same process to the determination of free bromine and chlorine, other members of the halogen group, to the estimation of combined iodine, and, indirectly, to the determination of the oxidizing power of certain oxidizing reagents.

The silver best adapted for this process is obtained electrolytically in a very finely divided state, being deposited as a black mass (probably silver hydride†) upon a small moving cathode. As long as the mass adheres to the electrode it remains perfectly intact but as soon as it is shaken off into the solution it immediately turns to a dull gray color, the hydrogen escapes, and the silver settles to the bottom in a fine flour-like powder. The mass of silver hydride should not be allowed to adhere to the electrode after it begins to change color, as the silver then collects in a crystalline form which does not absorb iodine readily.

Determination of Free Bromine and Chlorine.

In applying the process to the determination of bromine and chlorine a definite amount of the aqueous solution of these haloids was introduced into a flask containing an excess of potassium iodide made acid with hydrochloric acid and the whole shaken in an atmosphere of hydrogen with a weighed amount of silver. The residue of silver and silver iodide was collected in a Gooch crucible, washed, dried, and weighed. The increase in weight of the silver should represent the weight of iodine liberated from the iodide and from this the amount of halogen may be easily calculated. Table I shows the results of three determinations with bromine and five determinations with chlorine in which the average error falls within 0·0002 grm.

Determination of Potassium Iodide.

In applying the process to the determination of combined iodine a definite amount of a solution of potassium iodide, previously standardized by the distillation method with sul-

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* This Journal, xxviii, 33, 1909.

† Bartlet and Rice, Am. Chem. Jour., xix, 49.

TABLE I.

Silver taken grm.	Halogen taken grm.	Iodine found grm.	Calculated amt. of halogen grm.	Error grm.
(a) Determination of bromine.				
3·0000	0·0213	0·0336	0·0211	−0·0002
3·0000	0·0426	0·0678	0·0427	+0·0001
3·0000	0·1065	0·1694	0·1067	+0·0002
(b) Determination of chlorine.				
3·0000	0·0161	0·0574	0·0160	−0·0001
3·0000	0·0322	0·1146	0·0320	−0·0002
3·0000	0·0322	0·1145	0·0320	−0·0002
3·0000	0·0322	0·1141	0·0318	−0·0004
3·0000	0·0483	0·1716	0·0479	−0·0004

phuric acid and potassium hydrogen arseniate,* was introduced into a flask with an excess of the calculated amount of an oxidizing reagent (usually potassium nitrite or hydrogen peroxide), the whole made acid with hydrochloric acid, and shaken with a weighed amount of silver. The increase in the weight of the silver indicates the amount of iodine liberated from the potassium iodide and from this the amount of potassium iodide may be easily calculated. Table II shows the results of five determinations with potassium iodide in which the average error is −0·0002 grm. between limits of −0·0005 and +0·0002 grm.

TABLE II.

Determination of potassium iodide.

Silver taken grm.	KI taken grm.	Iodine found grm.	Calculated amt. of KI grm.	Error grm.
2·7803	0·1144	0·0872	0·1141	−0·0003
3·0028	0·1346	0·1026	0·1342	−0·0004
2·7800	0·1279	0·0978	0·1281	+0·0002
2·0008	0·1279	0·0974	0·1274	−0·0005
3·0001	0·1346	0·1029	0·1346	±0·0000

Determination of Oxidizing Reagents.

The process has also been applied to the indirect determination of several of the common oxidizing reagents with a view to showing that it may be used for the estimation of oxidizers that will liberate iodine quantitatively. In these experiments definite amounts of the oxidizer, standardized in the usual way, were added to an excess of a solution of potassium iodide acidified with hydrochloric acid, and the whole shaken with a weighed amount of silver in an atmosphere of hydrogen. The value of the oxidizer is then calculated from the increase in weight of silver which represents the amount of liberated iodine. Table III shows the results obtained in the determination of potassium permanganate, hydrogen peroxide, potassium dichromate, and ferric chloride, in all of which the error is well within experimental variation.

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* Gooch and Browning, this Journal, xxxix, 188, 1890.

TABLE III.

Silver taken grm.	Oxygen represented by oxidizer grm.	I found grm.	Calculated amt. of oxygen grm.	Error grm.
(a) Determination of potassium permanganate.				
3·0000	0·0123	0·1956	0·0123	±0·0000
3·0000	0·0123	0·1936	0·0122	—0·0001
3·0100	0·0123	0·1964	0·0124	+0·0001
3·0100	0·0123	0·1968	0·0124	+0·0001
4·0101	0·0185	0·2926	0·0184	—0·0001
4·0101	0·0247	0·3886	0·0245	—0.0002
(b) Determination of hydrogen peroxide.				
3·0000	0·0202	0·3200	0·0202	±0·0000
3·0000	0·0202	0·3214	0·0203	+0·0001
3·0100	0·0404	0·6427	0·0405	+0·0001
3·0000	0·0311	0·4937	0·0311	±0·0000
3·0000	0·0322	0·5128	0·0323	+0·0001
3·0000	0·0606	0·9590	0·0604	—0·0002
(c) Determination of potassium dichromate.				
3·0000	0·0080	0·1272	0·0080	±0·0000
3·0000	0·0160	0·2552	0·0161	+0·0001
3·0000	0·0201	0·3141	0·0198	—0·0003
3·0000	0·0402	0·6390	0·0403	+0·0001
3·0000	0·0160	0·2552	0·0161	+0·0001
3·0000	0·0160	0·2571	0·0162	+0·0002
(d) Determination of ferric chloride.				
3·0000	0·0218	0·3470	0·0219	+0·0001
3·0000	0·0218	0·3476	0·0219	+0·0001
3·0000	0·0437	0·6922	0·0436	—0·0001
3·0000	0·0218	0·3489	0·0220	+0·0002
3·0000	0·0262	0·4183	0·0264	+0·0002
3·0000	0·0218	0·3516	0·0222	+0·0004

The results obtained fully justify the statement that metallic silver may be used for the determination of free bromine and chlorine, and combined iodine, and for the estimation of the oxidizing power of those reagents whose reaction with potassium iodide is definitely known to set free iodine quantitatively.

ART. XXVIII.—*Discharges of Electricity through Hydrogen*; by JOHN TROWBRIDGE.

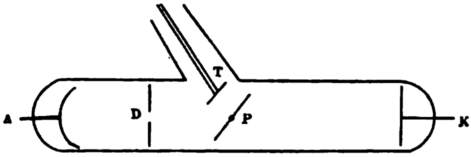
1. Reflection of Cathode Rays.
2. Striæ.
3. A method of rectification of alternating discharges.
4. The Doppler effect.

Reflection of Cathode Rays.

IN the course of this paper I shall refer to certain hydrodynamic analogies which the discharges of electricity through gases present; but not with the conviction that in these discharges we have to deal solely with questions of flow. The complicated phenomena give large scope both to theories of flow and molecular theories; the hydrodynamical analogies are more striking in discharges through gases at comparatively high pressures; while molecular theories apply best in highly rarefied gases. There seems to be a certain continuity here similar to that between motions of matter in the liquid state and in the gaseous state, when such matter is subjected to forces that can produce movement or flow of the particles.

The condition of electrical discharges in a tube represented in fig. 1 remind one of the flow of a fluid, interrupted by a plane lamina. A is a cathode, K an anode, D a diaphragm, P a plane lamina which can be moved about an axis perpendicular to the plane of the paper: fig. 1 being a plan of the discharge tube. P can also serve as an anode.

FIG. 1.



At the striæ stage the electrical conditions in the tube are very little modified by turning the lamina through small inclinations to the line of discharge. The striæ remain practically unaffected in shape and position until the angle between the normal to the lamina and the axis of flow reaches 50°. This phenomenon is analogous to the case of a lamina subjected to the flow of a liquid (Lamb's hydrodynamics, p. 94 and p. 111). It is also analogous to the conditions presented by the impact of wind on sails fronts.

By means of a side adjunct, a thermopile, T, was introduced in order to measure the heat excited by the reflection of the cathode rays passing through the diaphragm D and being reflected from the lamina, when the latter was inclined to the axis of the cathode rays at varying angles. Here also there was an action similar to the reflection of a stream of liquid from the lamina, proceeding in the direction of the cathode rays. The angle between the normal to the lamina and the axis of flow or discharge could vary largely without affecting the amount of heat from the reflected cathode beam, shown by the thermopile.

Striæ.

The striæ, or stratifications in Geissler tubes, constitute a very beautiful and mysterious phenomenon of the discharge of electricity through gases, and if one could follow perfectly the mechanism involved one could feel sure of having penetrated far into questions of the method of propagation of electricity. There seems no reason to doubt that the striæ are phenomena of ionization; but the regularity of the striæ leads one to ask if this regularity could arise from some pulsation or rhythmical action—the ionization being, so to speak, on top of such rhythmical action. When the striæ are excited by a storage battery they are perfectly steady, and when it is certain that there are no breaks in the circuit a telephone introduced into

Fig. 2.

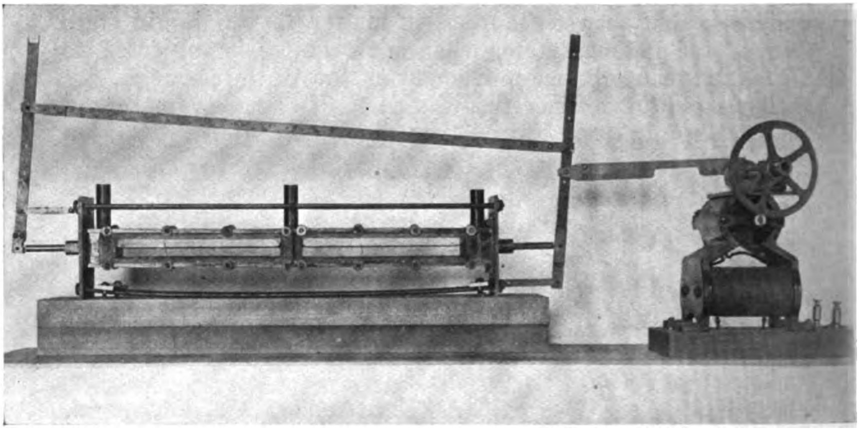


Fig. 2 represents an apparatus by means of which two pistons driven by a motor in opposite directions cause waves in a trough filled with water.

the circuit is silent; moreover, a large self-induction included in the circuit does not affect the striæ.

Under certain conditions the current from a storage battery oscillates, or pulsates, but such oscillations or pulsations do not seem to modify the appearance of the stratifications. If, on the other hand, there is a flow from the cathode which pulsates at a different rate from a supposititious flow from the anode, one might expect striæ, or accumulation of ionic disturbances at regular intervals. An hydrodynamical analogy is afforded by the motion of two pistons moving against each other at different rates in a channel filled with water.

FIG. 3.

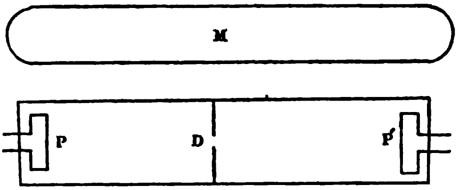


FIG. 3 shows the arrangement in plan by means of which the ripples are studied. M is a mercury lamp of the Cooper-Hewitt form. This is placed directly behind the trough containing the pistons. The surface of the water, totally reflecting the light, forms a dark line which, under the motion of the pistons, undulates in waves which can be studied by instantaneous photography. P and P′ are the pistons, and D is a diaphragm with a rectangular orifice.

FIG. 4.

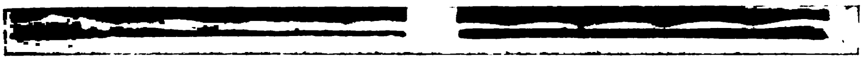
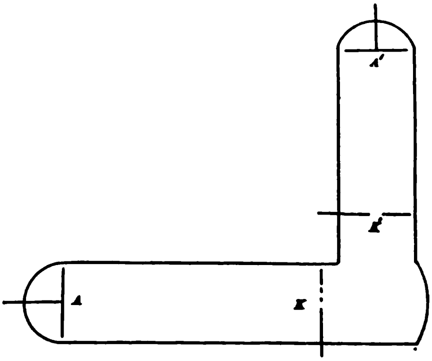


FIG. 4 represents a case in which P moves twice as fast as P′. The waves are formed nearer the slower-moving piston. The method seems to be useful in studying ripples and waves.

All who have worked in the field of discharge of electricity through gases must recognize the suggestiveness of the theory of ionization by collision, especially with reference to striæ; but one who was ignorant of this theory, seeing the action of the cathode in driving back striæ into the anode, might attribute this action to an actual repelling force, arising from the cathode. When this supposititious force is diverted by a magnet the striæ appear and more current flows. One ignorant of the many facts of ionization by collision might further suppose that heavier particles of slower motion might be held back by swifter particles issuing from the cathode. These views of a mind not biased by ionization theories would appear to be supported by the phenomena presented by the tube represented in fig. 5.

One branch of this tube is at right angles to the other branch. There are two anodes, A and A′, and two perforated cathodes, K and K′. When a multiple circuit is formed by leading in the current to the two anodes and out by one cathode, K, striæ form in the branch A′K′ after they disappear in the branch AK; and they persist in A′K′, when the branch AK appears to be nearly at the X-ray stage. One looking at the branch A′K′ would suppose that the rarefaction of the entire tube was low; and gazing at the branch AK would think it very high. The bend in the tube acts like a magnet in allowing the striæ to emerge from the anode A′; and it does this by enfeebling by reflection the effect of the cathode rays in the branch A′K′.

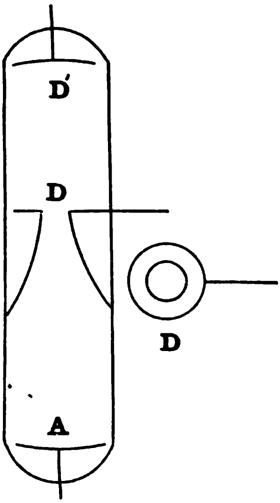
Fig. 5.



The function of the cathode beam seems to be twofold; it forces back the striæ; and at higher exhaustions it ionizes the gas; for the current ceases to flow at high exhaustions when the cathode beam is strongly diverted by a magnet. These functions are illustrated by the phenomena in a tube represented in fig. 6.

Between the anode, A, and a cathode, D, the glass tube is constricted. The cathode D is a circular disc with an orifice a little larger than the glass orifice. The cathode rests upon the walls of this orifice, presenting no metallic surface toward the anode A. The cathode beam produces fluorescence toward D′ and is marked in the direction toward A by a white beam which produces hardly a perceptible fluorescence. The latter beam does not come from the metallic surface of the cathode; but seems to come from the gas in the region DD′. At comparatively high exhaustions this latter portion of the cathode beam ceases to ionize the gas; the current ceases and the potential between A and D rises to the full potential of the battery, indicating an open circuit. When, however, D′ is made the cathode, the current is immediately re-established and the cathode beam from D′ ionizes the gas between D′ and A. The tube acts as a rectifier; for when D is made the anode and A the cathode a current passes; on reversal of the current, as I have said, no current passes in the opposite direction.

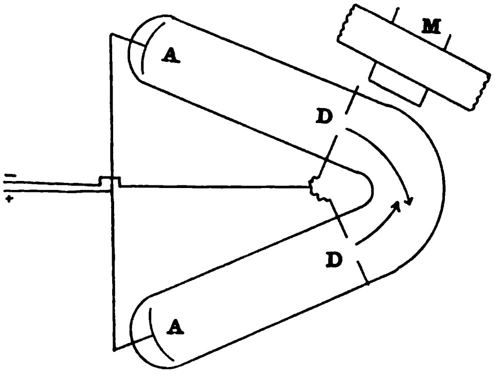
Fig. 6.



It is interesting to observe the effect of a transverse magnetic field on the discharge in this tube when A is made a cathode and D′ an anode and striæ appear in the portion DD′. The magnetic field placed near A diverts the cathode beam and striæ advance in the portion DD′. While this field is still on, another transverse magnetic field placed near D′ diverts the striæ independently of the action of the field at A. This indicates the well-known fall of potential from striæ to striæ.

The rectification observed under proper conditions in the tube fig. 6 suggests other forms of tubes by which rectification can be produced. Even with a straight cylindrical tube the current can be stopped at high exhaustions by touching the outside of the tube with the finger, thus diverting the cathode

Fig. 7.



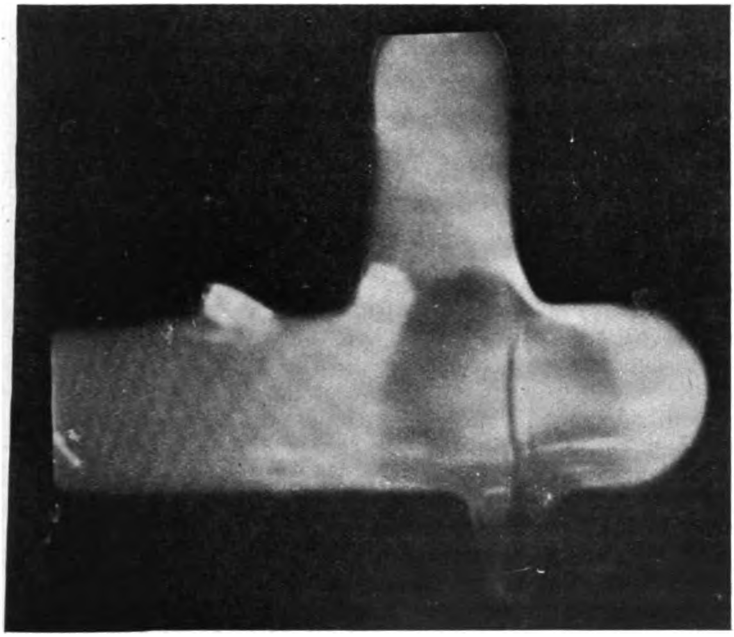
beam by electrostatic action; it readily passes when the current is reversed. The phenomenon of rectification is shown in a practical way in the U-shaped tube represented in fig. 7, which is provided with two anodes, A and A, and two cathodes, D and D′. The cathodes have orifices at their centers. The two anodes are connected together, and also the two cathodes—the tube forming a multiple circuit. A transverse magnetic field can be so placed near one cathode that no current will pass in the branch of the tube of which it is a part, while the current passes freely in the other branch of the U tube. This form of tubes rectifies an alternating current.

The apparent repelling, or driving back action, of the cathode beam on striæ is shown in a suggestive manner in a straight cylindrical tube when a diaphragm is inserted between the anode and the cathode. We will take for illustration one branch of the U-shaped tube (fig. 7), and suppose that the current is led into the tube at A and out at D. A metallic diaphragm with a small hole at its center is inserted in the tube about one-third of the distance between A and D, measured from the cathode to anode, the latter also having an orifice at its center. The striæ are slowly driven back by the cathode rays as the exhaustion proceeds. At a definite stage of this exhaustion a stria takes refuge behind the diaphragm near the anode, where it is protected from the driving back action of the cathode rays; finally at higher exhaustions this stria is driven through the orifice in the anode and shelters itself behind the anode.

At a higher state of rarefaction a stria issues from the orifice in the anode and this also shelters itself behind the diaphragm on the side toward the anode. There are, thus, three definite stages of stratification in this form of tube. At a pressure of four centimeters fine striæ appear on the side of the orifice in the diaphragm opposite to the anode. These soon disappear with increasing rarefaction. At a pressure of approximately 3^{mm} a large stria shelters itself behind the diaphragm opposite the anode. This disappears with diminishing pressure; and at a pressure of approximately 15^{mm} a large stria wells up out of the orifice in the anode and takes a similar place near the diaphragm. When the state of canalstrahlen is reached, all striæ have been driven into the anode. Can we regard these strahlen as a stratification which cannot be driven back by the cathode rays? In this form of tube we find evidence of successive states of stratification which may depend upon positive rays of different velocity.

When we turn our observation of stratification in the neighborhood of the cathode instead of in the neighborhood of the anode, we find that a stratification always takes place on the glass wall close to the entrance of the cathode, or to its sealing in place. It can be produced equally well by causing the cathode to approach the wall of the tube opposite to the sealing in place. Fig. 8 represents the phenomenon in a tube with a dome-shaped chamber near the electrode. We seem to have two dissected striæ; one on the wall of the tube nearest to the cathode, which provides a beautiful light blue cathode beam thrown into the dome; and another stria on the opposite wall of the dome. The original cathode beam excites both positive and negative rays in these striæ.

Fig. 8.



In considering these detached striæ it seems that the cathode rays in striking the glass walls can excite both positive and cathode rays.

When a spark gap is inserted in a circuit containing a discharge tube which is properly exhausted to the striæ stage, the latter apparently disappears, the light of the tube becomes more brilliant and fluorescence is generally manifested. This is also the case when a condenser is discharged through the tube. The eye cannot perceive any evidence of stratifications; for the brightness of the pilot spark, together with the fluorescence both of the gas and the glass walls, effectually shield any striæ of lesser radiance which might be present. It is not possible to employ the revolving mirror. The only method which seemed to promise any results in detection of possible stratifications was the employment of a portrait lens of large aperture—four inches—in photographing single discharges. Accordingly a discharge tube was filled with hydrogen and exhausted to the striæ stage. A condenser of ·02 mf. capacity was charged to a difference of potential of 10,000 volts and discharged through the rarefied tube by flat copper bands of inappreciable self-induction. The photographs showed unmistakable striæ, superposed upon the general illumination of the tube. It is difficult to reproduce the photographs by half tones.

With an anode consisting of a rim of wire placed in a cylindrical tube $\cdot 5^{mm}$ internal diameter a striation is formed at a short distance from the anode by condenser discharges and there are traces of similar striations at greater distances along the tube. If these striations are formed by ionization by collision, the time of ionization is that of the duration of the pilot spark, a time which at present is beyond our power of measurement.

Doppler effect.

When two anodes and two cathodes are employed in the form of tube represented in fig. 7, there are two canalstrahlen which emanate from orifices in the cathodes in opposite directions. One might suppose that the Doppler effect would be modified by collision of the particles in these rays and that the effect would certainly be less than when only one anode and one cathode were employed—the current thus passing through but one branch of the U-tube. It is true that the difference of potential is less between Δ and D when the tube is coupled in multiple circuit than when only one branch of the tube is connected to the battery; but this difference in the case I studied was comparatively small. With both branches of the tube constituting a multiple circuit there were two strong canalstrahlen passing through the orifices in D which were undistorted and which gave the same Doppler effect which was obtained when only one branch of the tube was excited. It seems difficult to reconcile this result with any theory of flow.

Conclusions.

1. The striæ in Geissler tubes are analogous to waves set up in narrow channels by opposite pulsations of different periods.
2. Striæ are greatly influenced by the direction of cathode rays.

Certain forms of tubes, described in this article, can imitate the action of a transverse magnetic field in apparently increasing the conductibility of the rarefied gas and restoring the condition of stratification.

3. Striæ can be formed by condenser discharges; and such striæ lead one to suppose a time of ionization beyond our power of measurement.

By means of a suitably placed diaphragm, successive stages in stratification can be produced.

4. By modification of the form of discharge tubes rectification of alternating discharges is possible.

5. The Doppler effect in hydrogen is not modified by causing two canalstrahlen to oppose each other.

Jefferson Physical Laboratory,
Harvard University.

ART. XXIX.—*A New Pennsylvania Meteorite;* by O. C. FARRINGTON.

To the iron meteorites known from Pennsylvania, Bald Eagle, Pittsburg and Mount Joy, a fourth is now added. This last cosmic accession was found in 1907 on a farm about seven miles north of Shrewsbury, York County, Pennsylvania. It was discovered by being struck by a plow while plowing and attracted attention on account of its unusual weight. As the region is one in which more or less brown limonitic iron ore occurs, the meteorite was supposed by its finder to be an unusually heavy specimen of such ore and as such was shown to Mr. F. Justice Grugan of Philadelphia when in the vicinity in June, 1909. Mr. Grugan, in whose possession the meteorite now is and to whom the writer is indebted for the history here given, at once recognized the meteoric nature of the mass, and took steps for its preservation. He also instituted a search for any associated specimens that might be in the vicinity. In this he was successful to the extent of finding several fragments that had been distributed as curiosities, but no important additional individuals were found. The smaller pieces obtained were reported to have been found about three-quarters of a mile northwest of the main mass. If this distribution was a natural one, a southeasterly course of the meteor is indicated. The fragments and mass placed in the hands of the writer for examination had evidently all belonged to a single individual. The main mass as received weighed twenty-four pounds and the fragments three pounds more, giving a total weight to the meteorite as now known of twenty-seven pounds (12·2 kgs.). The form of the meteorite as restored by adding the fragments is roughly rhombohedral, with dimensions of about six inches (15^{cm}) on a side. At the same time there is much rounding of the solid angles and there are many depressions and irregularities which make the above characterization of the form only an approximate one. Owing partly to decomposition from lying in the soil and partly probably to rough handling, the appearance of the original surface of the meteorite remains over less than half the mass. Where seen it shows the usual rounded and smooth exterior of iron meteorites with broad, shallow pits, the broadest being about three inches (7^{cm}) in diameter. There has been considerable alteration of this surface through weathering, so that its substance has become more or less friable and limonitic in character. This alteration appears to extend in places to a depth of about half an inch (1^{cm}). Where the original surface is not present the meteorite shows a jagged, fractured appearance and exhibits typical octahedral structure. It is probable that over such portions the original surface has disintegrated and fallen away, though the appearance at one point would indicate a rending of the mass in the air like that shown by one of the Glorieta Mountain individuals.

On account of oxidation the mass as a whole presents a generally rusty brown color with spots of a green incrustation, due doubtless to the formation of some nickel salt. The undecomposed nickel-iron is easily cut by a file, but is not malleable owing to a well-developed laminated structure. Under the hammer, therefore, it is inclined to crumble. Plates of bronze-yellow, flexible, magnetic tænite can be easily separated both from the decomposed and undecomposed nickel-iron.

FIG. 1.

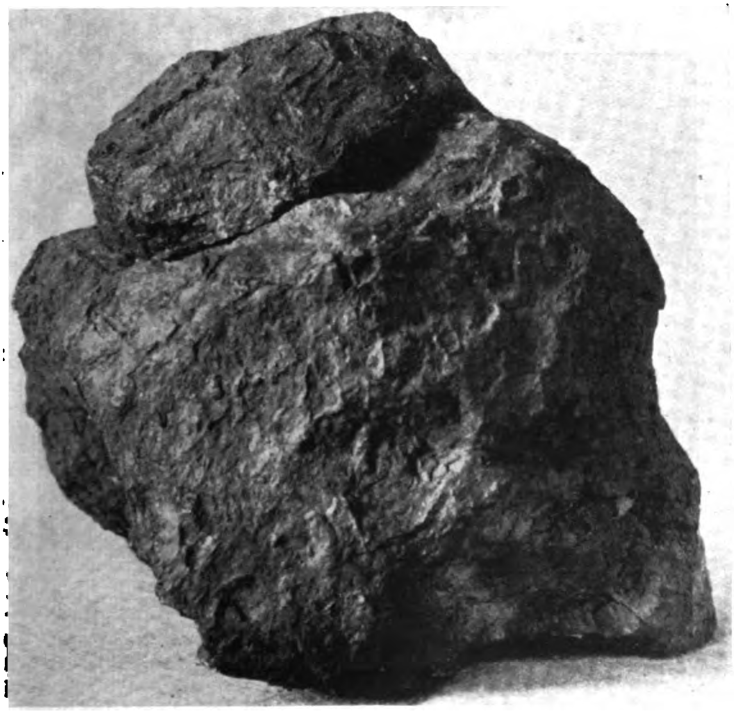


FIG. 1. Shrewsbury meteorite—3/5 nat. size.

Analysis of the meteorite by Dickman and Mackenzie of Chicago gave the following result:

Fe	Ni	Co	S	P		
90·84	8·80	tr.	·01	·29	=	99·94

Sections of the meteorite show a firm, homogeneous interior with little or no disintegration. Broad, straight lamellæ almost entirely prevail. These lamellæ average a little over one millimeter in width, thus placing the meteorite in the group of medium octahedrites. For the most part the lamellæ show simple, broad bands of kamacite, but some of these are seen on closer examination to be made up of smaller lamellæ grouped together. The kamacite shows considerable hatching, generally in a single direction. Where fields occur they appear to be mainly of two kinds: 1, those made up of numbers of minute tænite foliæ with parallel arrangement and parallel to the adjoining bands, and 2, those made up of kamacite grains bordered by tænite and showing a more or less divergent arrangement. Accessory constituents are comparatively abundant and scattered irregularly over the section though somewhat more numerous toward the periphery. They include troilite and schreibersite, the troilite occurring in spheroidal and the schreibersite in hieroglyphic forms. The troilite is characterized by a bronze-yellow color and dull luster, the schreibersite by a tin-white color and shining luster. One troilite nodule in the section especially studied by the writer is nearly circular in form, 2^{cm} in diameter and has an irregular border of schreibersite. In other places the troilite has a more nearly vein-like distribution and is more or less mixed with schreibersite. Hieroglyphic schreibersite occurs at several points, usually in groups of three. The grains are from 4 to 8 millimeters in length. Swathing kamacite from 2 to 4 millimeters in width surrounds the scheibersite inclusions, but there is none about the troilite.

FIG. 2.

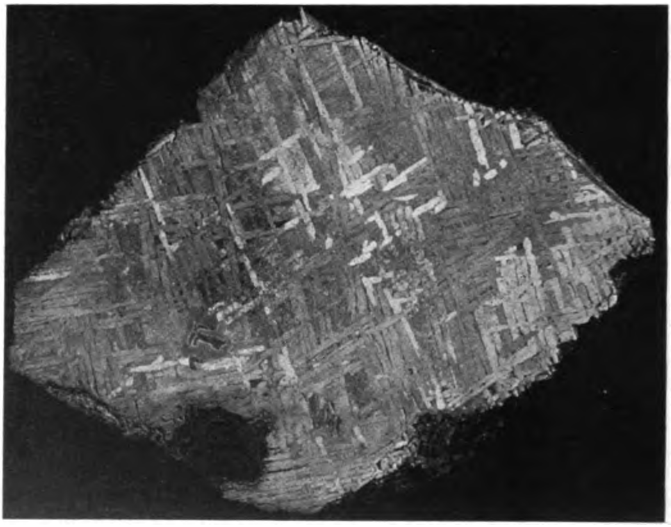


FIG. 2. Etched section of Shrewsbury meteorite—1/2 nat. size.

ART. XXX.—*Remarks on the Pentamerous Symmetry of the Crinoidea;* by AUSTIN H. CLARK.

THE pentamerous symmetry of the echinoderms is now admitted to be a feature of phylogenetically secondary importance—a radial symmetry superimposed upon a primarily bilateral symmetry and so perfectly developed as almost entirely to mask the original condition. It has been pertinently suggested that the sedentary life of the animals has induced a radial arrangement of their structures, analogous to what has occurred in certain other groups, though in the echinoderms this has been carried so far as to result in a complete absence of any head region, and, consequently, a complete decentralization of the nervous system, so that, in many cases, the only trace of the original bilateral symmetry is found in the digestive system. In the Astroradiata* (Asteroidea and Ophiuroidea) even this has yielded to the radial tendency, through here the water-vascular system, as evidenced by the so-called "stone-canal," shows indications of a former bilateral arrangement.

The larva of all echinoderms are bilaterally symmetrical, and pronouncedly so, the pentamerous symmetry only appearing when the adult form is acquired. The astroradiate echinoderms are all, except for the stone canal, radially symmetrical in every respect; but in the heteroradiate forms (Pelmatozoa, Echinoidea, and Holothuroidea) there is often, one might almost say usually, a more or less pronounced leaning toward the bilateral type, as seen, for instance, in the Comasteridæ among the crinoids, in the clypeastroids and spatangoids among the urchins, and in the Elasipoda, and in such forms as *Lophothuria* and *Psolus*, among the holothurians. There are two possible explanations of this bilateral condition in the heteroradiate echinoderms; (1) the animals may never have attained the perfected radial symmetry, or (2) they may have passed through a radially symmetrical condition and, reacquiring the habit of moving in a definite direction, have again taken on a bilateral habit, this bilateral condition having been superimposed upon the previous pentamerous condition, which itself was superimposed upon the primitive bilateral state. It is probable that the so-called "irregular" urchins (the clypeastroids and spatangoids) as well as the Elasipoda and other bilateral holothurians exemplify the latter condition, while certain of the Pelmatozoa furnish an instance of the former. It is among the crinoids, then, of the living echinoderms that an explanation of the origin of pentamerous symmetry must be sought, and a review of the data gleaned from a study of certain species offers some points of considerable interest. But just because certain of the crinoids appear never to have attained a true and complete radial symmetry, it does not at all follow that the marked bilateral arrangement of all types can be thus explained; for instance, in the recent representatives of the family Comasteridæ there are several species having the arms arising from the two posterior rays much shorter than the others, and devoid of ambulacral grooves or tentacles. This is a bilateral symmetry derived through a pentamerous symmetry clearly, for in the less specialized species belonging to the same genera, and in their own young before adolescent autotomy, the two posterior rays and the arms arising therefrom are just like all the others.

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* American Naturalist, vol. xliii, p. 686, Nov., 1909.

That classical genus *Antedon*, the "*Comatula*" of most text-books, represents a form with the most highly perfected pentamerous symmetry, yet exhibiting no advance whatever toward the more highly specialized secondary bilateral symmetry seen in the comasterids. *Antedon* is strictly pentamerous in all respects, excepting only the digestive system; but that this pentamerism is really quite superficial is strikingly shown by a variant described by Professor Bateson* in which one of each of the posterior pairs of arms was abnormally palmate. It would seem, then, that *Antedon* was a good genus in which to search for an explanation of the origin of pentamerism.

Dr. P. H. Carpenter had the good fortune to be able to examine several four-rayed comatulids, most of them belonging to the genus *Antedon*; and it is a fact of the highest interest that in every case *it was the anterior ray, the one directly opposite the anal area, that was missing.* The U. S. National Museum possesses a four-rayed specimen of that magnificent comasterid *Comanthus polycnemis*, which was brought from the Philippine Islands; on examining it I found that here again it was the anterior ray that was missing. Such a remarkable coincidence of observations can mean but one thing; there must be some good reason why the anterior ray should be deficient rather than any of the other four. Since we can safely say that there is no physiological reason why the anterior ray should be suppressed in preference to the others—indeed in the case of comasterids one would think that one of the normally abortive posterior pairs would be the first to

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*Proc. Zool. Soc. London, 1890, p. 584, fig. 4. The eleven and twelve armed specimens of *Antedon* described by Dendy and Carpenter are not bilaterally arranged; but probably they arose through accident and are not congenital, not being, therefore, strictly comparable.

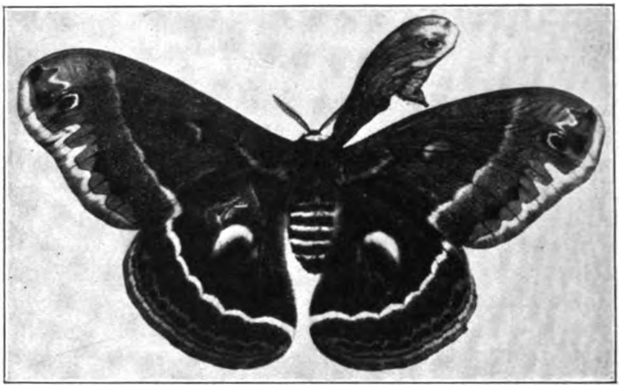
disappear, since it is quite useless for the collection of food—we are forced to look for some phylogenetic cause.

Young crinoids are, as has been mentioned, bilaterally symmetrical; all the four-rayed adults of the comatulids so far observed are bilaterally symmetrical; the normal five-rayed adults are the equivalent of the four-rayed adults, plus the interpolation of an additional ray between the two of the anterior pair. The more or less frequent reversion of the five-rayed crinoids to a four-rayed form (a permanent condition in *Tetracrinus*) would appear to be an index pointing back along the phylogenetic path travelled by the race: and this index becomes all the more significant when we glance at the record of six-rayed variants in which there is no such uniformity of place of interpolation.

It would appear as though the evidence pointed to an original bilateral condition among the adult crinoids in which there were two pairs of body processes that had become, through similarity of function, the same; in other words, a bilateral condition which had become as well, through induced radial symmetry due to inactive habit, quadriradial. We may readily imagine that, by sporadic variation, an additional ray might sometimes be produced between the two of the anterior pair, especially in animals of such remarkable regenerative powers as the crinoids. This additional ray would be just like those on either side of it; and in a sessile animal it would cause no inconvenience but would, on the contrary, be of distinct advantage in furnishing a very marked increase in food-collecting power. Animals with this additional ray would therefore have, in the case of sessile forms like the crinoids—passive feeders which must wait for their food to come to them—a great advantage in the struggle for existence, and we might well imagine that nature would be quick to take advantage of such a variant, and to fix permanently this pentamerous condition.

If we can admit that the four-rayed condition which, so far as is known, always arises from the loss of the anterior ray, is a true phylogenetic index—and there is no good reason why we should not—then we would be led to the conclusion that the crinoids are primarily animals possessing a bilateral symmetry, with two pairs of similar appendages, an anterior and a posterior, upon which a secondary pentamerous symmetry has been superposed, due to interpolation of one half of one of the bilaterally symmetrical pairs of appendages between the two components of the original anterior pair.

It might be urged that supernumerary paired appendages would be unlikely to put in an appearance except in pairs; but we find instances of just that thing in other widely different animals which possess two similar pairs of appendages like our theoretical ancestral crinoid. I may mention in this connection three-legged (five-limbed) chickens among the birds, and five-winged butterflies and moths (in cases where the additional wing does not replace a leg). In one case of the latter, a beautiful female of *Platysamia cecropia*, which has recently come under my notice, the similarity to the theoretical phylogenetic condition among the crinoids is very striking, for the additional wing (which unfortunately failed to spread properly)



Specimen of *Platysamia cecropia* with an additional primary inserted just anterior to the normal right primary.

is inserted anterior to one of the primaries, where, were the animal sessile and incapable of motion, it might, through fixation in subsequent generations, very well give rise to as truly a pentamerous condition as is exhibited by the crinoids.

Although I have treated in detail only the evidence brought out by the crinoids, I have no doubt that the pentamerous symmetry in all the other groups has arisen in the same way, by the interpolation of an extra ray between the two original anterior rays; and that this accounts for the excess of plasticity of this ray in certain groups, and its more or less frequent suppression in others. In six-rayed specimens almost invariably the sixth ray is obviously formed by a more or less complete division of one of those already existing—a sort of echinodermal polydactylism—and these six-rayed examples, therefore, are very suggestive in indicating that echinoderm symmetry is not by any means radial, but is a composite of five equivalent parts, two paired and one, the anterior, odd.

The echinoderms as known to us are extremely ancient animals, zoologically speaking, so ancient that they were brought to their present state of perfection, or were even more highly specialized, in the earliest geologic epochs of which we have any record. The enormous time through which they have passed without any appreciable change toward further specialization has resulted, by the operation of the law of acceleration of development, in pushing the various ontogenetic steps further and further back until all such stages as the biserial arrangement of the crinoid arm, the change from bilateral to pentamerous symmetry, the reduction and transformation of the ambulacral plates in the crinoids into division series, etc. have been entirely lost. The echinoderms as a whole I believe can be compared with the other invertebrate groups in their mode of development only in the way that the curiously specialized *Gecarcinus* can be compared with other crabs, or *Hylodes* with other frogs; in other words, they form a group in which extreme specialization and its effect upon the earlier stages of the ontogeny has obscured or obliterated much of the phylogenetic data ordinarily available.

Larval echinoderms are as extraordinarily specialized as the adults, but along radically different lines; many of them have specially developed skeletons, entirely different from those of the adults, which are lost in later life. It seems to me that the echinoderm larvæ, owing to their extraordinary specialization, must be treated almost as a different class of animals from the adults, specialized along entirely different lines, and fitted for an entirely different mode of life; and that we can expect to learn little more about the interrelations of the echinoderm groups from the study of their larvæ than we could of the relationships of the groups of lepidoptera, diptera or coleoptera from a study of their caterpillars or maggots.

ART. XXXI.—*An Association of Enargite, Covellite, and Pyrite from Ouray Co., Colorado;* by WILLIAM M. THORNTON, JR.

IN October, 1906, Professor William H. Echols received a curious sample of copper ore from the Genesse Vanderbilt mine in the Red Mountain district, Ouray county, Colorado. The specimen was seen to consist of three distinct metallic minerals, which were subsequently identified by physical properties, behavior before the blowpipe, and quantitative analysis as enargite, covellite, and pyrite.

General Description.

The enargite is closely interlocked with pyrite—both growing out from a quartz gangue. The color of the enargite is dark grey; and the luster metallic. The structure is columnar. The cleavage is easy in one direction. Specific gravity=4·49. A few crystals are present but badly crushed and distorted. The covellite joins the other two minerals, and includes here and there a little pyrite or gangue. The color is indigo-blue and the luster sub-metallic. The structure is foliated, and the mineral can be easily cleaved into thin plates.

Analysis of enargite by Wm. M. Thornton, Jr.

Copper	50·82	per cent.
Zinc	0·33	"
Arsenic	17·28	"
Sulphur	32·53	"
Silver	None	"
Iron	Trace	"
	100·96	

Corresponds approximately to the formula: $Cu_3AsS_4 \Bumpeq 3Cu_2S, As_2S_5$.

Analysis of covellite by John E. Seabright.

Copper	68·38	per cent.
Sulphur	32·51	"
	100·89	

Corresponds to the formula: CuS.

Methods of Analysis.—The enargite was first treated with nitric acid and the resulting mass thoroughly dried. A fusion was then made with sodium carbonate and potassium carbonate (weight for weight) and potassium nitrate, and the melt leached with water. An aliquot part (3/4) of the filtrate was concentrated for the precipitation of arsenic as ammonium magnesium arsenate. The precipitate was ignited to magnesium pyroarsenate. A trace of arsenic was recovered from the filtrate by hydrogen sulphide and weighed as arsenic trisulphide. In one-fourth the original solution the sulphur was determined as barium sulphate in the usual manner. The residue, consisting chiefly of copper oxide, was dissolved in sulphuric acid and a little nitric acid; and the copper precipitated with sodium thiosulphate, ignited under hydrogen sulphide, and weighed as cuprous sulphide. In the filtrate from the cuprous sulphide the zinc was precipitated by ammonium sulphide and ignited to the oxide.

The covellite was dissolved in nitric acid; and with the aid of potassium chlorate the separated sulphur was converted into one clean globule. The sulphur thus separated was weighed as free sulphur. One-fifth of the filtrate was employed to determine the remaining sulphur as barium sulphate. In two-fifths of the original solution the copper was estimated as above.

This cuprous sulpharsenate is not among the commonly occurring ores of copper. Cupric sulphide, as compared with cuprous sulphide, or ordinary copper glance, is rare. This association, therefore, is in the author's opinion a very interesting one and deserving the brief notice here given. It may also be mentioned that the minerals of this aggregate contain no silver, which is quite the exception for ores of the Red Mountain district.

Virginia Geological Survey,
University of Virginia,
January 22, 1910.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Detection of Sodium, Cæsium, and Rubidium.*—Some years ago W. C. **BALL** described some complex nitrites of bismuth, prepared from the yellow liquid obtained by the interaction of bismuth nitrate and sodium or potassium nitrite. Among these were the triple salt $Bi(NO_2)_3.2NH_4NO_2.NaNO_2$, and the double salt $Bi(NO_2)_3.3KNO_2.H_2O$, both very soluble compounds. On attempting to prepare similar rubidium and cæsium derivatives, it was found that dilute solutions of the nitrates of these metals produced yellow, crystalline precipitates with the reagent obtained from sodium nitrite and bismuth nitrate. These are triple nitrites of bismuth, sodium, and rubidium or cæsium, and their formation serves as a very useful method of detecting these metals in the presence of an excess of potassium. The reaction for cæsium is especially delicate. Furthermore, a reagent may be prepared by the addition of a cæsium salt to the product of the reaction of bismuth nitrate and potassium nitrite, which serves as a remarkably delicate test for sodium in producing a precipitate of the same triple bismuth-sodium-cæsium nitrite.

The bismuth-sodium nitrite reagent is best prepared by dissolving 50 g. of pure sodium nitrite in 100^{cc} of water, neutralizing with nitric acid if necessary, and adding 10 to 20 g. of powdered bismuth nitrate. The resulting orange-colored solution must then be filtered and kept in a well-stoppered bottle, as it absorbs oxygen and becomes turbid when exposed to the air. In using this reagent to test for rubidium and cæsium, the solution to be tested is added to a large excess of the reagent acidified with one or two drops of nitric acid to prevent the formation of a basic bismuth salt. In all these tests it is better to use nitrates or sulphates, rather than chlorides, on account of the tendency of bismuth oxychloride to precipitate when concentrated solutions of chlorides are used. The reagent gives a precipitate quickly with a 0·5 per cent solution of rubidium. Only heavy metals and cæsium interfere with the test, which affords an easy method for distinguishing rubidium from potassium, ammonium, lithium, thallium, etc. The precipitate is bright yellow and crystalline, and probably corresponds to the formula $Bi(NO_2)_3.2RbNO_2.NaNO_2$. The test for cæsium with this reagent is still more delicate, 1^{cc} of a 0·2 per cent solution of cæsium nitrate giving an immediate yellow crystalline precipitate with 4 or 5^{cc} of the reagent.

The reagent for sodium is prepared by dissolving 50 g. of potassium nitrite in double its weight of water, neutralizing with nitric acid, adding 10 g. of powdered bismuth nitrate, filtering, adding a 10 per cent solution of cæsium nitrate until the powdery yellow precipitate, invariably produced by traces of sodium present, ceases to be formed after keeping the liquid for several hours. The liquid is then filtered and the addition of cæsium nitrate continued until about 2·5 g. have been used. The reagent is most sensitive when a precipitate of yellow, hexagonal plates, a nitrite of cæsium and bismuth, is formed on further addition of the cæsium salt. With 2^{cc} of this reagent $0·1^{cc}$ of a 0·5 per cent solution of sodium, as nitrate, gave a considerable precipitate within 5 minutes, and by long standing it was found possible to detect as little as 0·01 mg. of sodium in the presence of much potassium salt. Most of the heavy metals interfere with this test, but zinc, cadmium, magnesium, barium, calcium, strontium, lithium, thallium and potassium do not interfere with it. The formula for the precipitate appears to be $5Bi(NO_2)_3.9CsNO_2.6NaNO_2$.

Preliminary experiments indicate that small amounts of sodium may be quantitatively determined very accurately by means of this method. The precipitate contains only 3·675 per cent of sodium.—*Jour. Chem. Soc.*, xcv, 2126. H. L. W.

2. *Volumetric Determination of Sulphates.*—Mitchell and Smith have worked out the details of a method for this purpose, which is based on well-known reactions, and which had been suggested, in its essential features, by Precht as early as 1879. They take a convenient quantity of a sulphate, dissolve it in water or pure hydrochloric acid, or, if necessary, dilute nitric acid, and then add a slight excess of 1/5 normal barium chloride solution. They then boil the mixture, make it neutral with ammonium hydroxide, add ammonium acetate, acetic acid, and a slight excess of 1/10 normal ammonium dichromate solution, make up the mixture to 100^{cc}, allow the precipitate to settle, take out 25^{cc} of the clear liquid and titrate it with 1/20 normal ferrous ammonium sulphate, using potassium ferricyanide as an external indicator, and taking the first tinge of green as the end point. They use ammonium dichromate on account of the fact that barium dichromate appears to carry down with it traces of the potassium salt. The method was tested with ammonium sulphate, sodium sulphate, potassium sulphate, zinc sulphate, magnesium sulphate, and copper-ammonium sulphate. With potassium sulphate there was evidence of adsorption, to the extent of nearly 2 per cent, but this was minimized by boiling the precipitate for several hours with a little dilute hydrochloric acid, neutralizing with ammonia, and proceeding as before. It is to be observed in applying this method that ammonium dichromate which is 1/10 normal in regard to oxidizing power, is only 1/30 normal in regard to precipitating power. The test analyses give very satisfactory results, and it is stated that, excluding weighings, five determinations can be made in an hour.—*Jour. Chem. Soc.*, xcv, 2198. H. L. W.

3. *The Action of Metals on Fused Caustic Soda.*—As there are conflicting statements in respect to the stability of sodium

hydroxide at high temperatures, and its action upon metals when heated in contact with them, **LeBlanc** and **Bergmann** have made an investigation of these matters. They find that caustic soda can be easily dehydrated, as far as accidental water is concerned, by heating it in a gold crucible to 400° C., and that it shows no tendency to give off water of composition at 720°. Gold is the only metal experimented with which is not at all acted upon at the temperature just mentioned. Silver and sodium, in the absence of air, cause the evolution of hydrogen alone, while under the same conditions platinum, copper, iron, nickel, aluminium, zinc and magnesium cause the evolution of both hydrogen and water vapor. The ideal reaction is $Me+xNaOH=Me(ONa)_x+xH$, so that the reason for the production of water in nearly all cases is somewhat obscure. This point the authors will study by means of further experiments.—*Berichte*, xlii, 4728. H. L. W.

4. *Transformation of Diamond into Graphite.*—**Vogel** and **Tammann** have investigated the temperature at which this change takes place. Splinters of diamond were placed in sealed porcelain tubes and heated in an electric furnace. At 1000° C. the change is exceedingly slow, and may not occur at all; at 1200° a considerable transformation takes place within 24 hours, and at 1500° the change is comparatively rapid. A piece of diamond, which was heated to 1600° in fused calcium silicate, so as to exclude air, was also changed superficially into graphite. —*Zeitschr. physikal. Chem.*, 69, 598. H. L. W.

5. *The Johns Hopkins University Circular, No. 2.* Pp. 92. Baltimore, Md., February, 1910.—The recent circular of the Johns Hopkins University has a double interest. It opens with a series of papers, seventeen in number, from the physical laboratory, edited by Professor Ames. Five of these are by Professor Wood, including two on his recent photography with infra-red and ultra-violet rays; three each by J. B. Whitehead, J. A. Anderson, and W. W. Strong, and others by A. H. Pfund, P. H. Edwards, and C. M. Sparrow. A list of recent publications (since April, 1906) by those who are, or have been, members of the University fills pages 55–76.

This circular also contains the record of the commemorative meeting held on December 19, 1909, of Professor Simon Newcomb, whose active connection with the University extended over the sixteen years from 1884 to 1900. The address delivered by Professor Milton Updegraff, of the U. S. Navy, is given in full.

6. *Meteorologische Optik;* von J. M. **Pernter**. IV Abschnitt; von **Felix M. Exner**. Pp. xviii, 559–799. Vienna, 1910 (Wilhelm Braümuller).—Earlier parts of this valuable work have been noticed in this Journal (see vol. xiii, 472, xxii, 81.) As will be recalled, the work as planned by Professor Pernter in 1901 was intended to embrace all the material dealing with meteorological optics, a field which has never been filled before. The author unfortunately died in December, 1908, before it was possible for

him to finish his task. The completion of the work, therefore, has been placed in the hands of his associate, Dr. Exner, who with much thoroughness and industry has prepared a well-arranged digest of the special subjects to be covered. As this field, however, is one to which he had not devoted particular attention, he disclaims any attempt at originality of presentation, except in regard to Lord Rayleigh's theory of the blue color of the sky. Some of the topics treated are as follows: The apparent form of the firmament; atmospheric refraction and the connected phenomena, as the Fata Morgana, scintillation, etc.; halos and rainbows and their explanation; the color and polarization of the sky, the weakening of light in the atmosphere and twilight phenomena.

II. GEOLOGY AND MINERALOGY.

1. *Publications of the U. S. Geological Survey*, GEO. OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from vol. xxviii, p. 557).

FOLIOS.—Geological Atlas of the United States.—No. 167. Field edition, in octavo form. Trenton, New Jersey–Pennsylvania Folio. Description of the Trenton Quadrangle: F. BASCOM, N. H. DARTON, H. B. KÜMMEL, W. B. CLARK, B. L. MILLER, and R. D. SALISBURY. Pp. 185; 2 maps. Structure section sheet, columnar sections, 3 figures.

No. 169. Watkins Glen–Catatonk Folio, New York; by HENRY S. WILLIAMS, RALPH S. TARR, and EDWARD M. KINDLE. Pp. 33, 3 colored maps, 37 figures.

PROFESSIONAL PAPERS.—No. 65. Geology and Water Resources of the Northern Portion of the Black Hills and Adjoining Regions in South Dakota and Wyoming; by N. H. DARTON. Pp. 105, 24 plates, 15 figures. See p. 267.

MINERAL RESOURCES of the United States. Calendar year 1908. Part I—Metallic Products. Pp. 816, 2 plates, 3 figures. Part II—Non-Metallic Products. Pp. 899, 1 plate, 6 figures. These important volumes, each with its own index, bring together the numerous separate chapters, prepared by many different authors, which have already been issued in advance. The general summary of mineral production in 1908, with which Part I opens, has been prefaced by W. T. THOM.

BULLETINS.—No. 378. Results of purchasing Coal under Government Specifications; by JOHN SHOBER BURROWS. With a paper on Burning the Small Sizes of Anthracite for Heat and Power Purposes; by DWIGHT T. RANDALL. Pp. 44.

No. 386. Pleistocene Geology of the Leadville Quadrangle, Colorado; by STEPHEN R. CAPPS, Jr. Pp. 99, 7 plates, 18 figures.

No. 390. Geology of the Lewistown Coal Field, Montana; by W. R. Calvert. Pp. 83, 5 plates, 1 figure.

No. 396. Paleontology of the Coalinga District, Fresno and Kings Counties, California; by Ralph Arnold. Pp. 173, 30 plates.

No. 397. Mineral Deposits of the Cerbat Range, Black Mountains and Grand Wash Cliffs, Mohave County, Arizona; by F. C. Schrader. Pp. 226, 16 plates, 37 figures.

No. 400. Iron Ores, Fuels, and Fluxes of the Birmingham District, Alabama; by Ernest F. Burchard and Charles Butts. With Chapters on the Origin of the Ores; by Edwin C. Eckel. Pp. 204, 17 plates, 19 figures.

No. 404. The Granites of Vermont; by T. Nelson Dale. Pp. 138, 5 plates, 25 figures.

No. 405. The Mercury Minerals from Terlingua, Texas; by W. F. Hillebrand and W. T. Schaller. Pp. 174, 6 plates, 44 figures.

No. 408. A Reconnaissance of Some Mining Camps in Elko, Lander and Eureka Counties, Nevada; by William H. Emmons. Pp. 130, 5 plates, 22 figures.

No. 409. Bibliography of North American Geology for 1908, with subject index; by John M. Nickles. Pp. 148.

No. 410. The Innoko Gold-Placer District, Alaska, with accounts of the Central Kuskokwim Valley and the Ruby Creek and Gold Hill Placers; by A. G. Maddren. Pp. 87, 5 plates.

No. 411. Results of Spirit Leveling in Ohio, 1898 to 1908, inclusive; compiled by S. S. Gannett and D. H. Baldwin. Work done in coöperation with the State of Ohio during 1901 to 1908, inclusive. Pp. 147.

No. 412. Tests of Run-of-Mine and Briquetted Coal in a Locomotive Boiler; by Walter T. Ray and Henry Kreisinger. Pp. 31, 9 figures.

No. 413. A Reconnaisance of the Gypsum Deposits of California; by Frank L. Hess, with a Note on Errors in the Chemical Analysis of Gypsum; by George Steiger. Pp. 36, 4 plates, 2 figures.

No. 414. Notes on Some Mining Districts in Humboldt County, Nevada; by Frederick Leslie Ransome. Pp. 75, 1 plate, 7 figures.

No. 416. Recent Development of the Producer-Gas Power Plant in the United States; by Robert Heywood Fernald. Pp. 82, 2 plates, 3 figures.

No. 418. The Fire Tax and Waste of Structural Materials in the United States; by Herbert M. Wilson and John L. Cockrane. Pp. 30.

No. 421. Results of Spirit Leveling in Illinois 1896 to 1908, inclusive; compiled by S. S. Gannett and D. H. Baldwin, in coöperation with the Illinois State Geological Survey during 1905 to 1908, inclusive. Pp. 74.

No. 423. A Primer on Explosives for Coal Mines. By

Charles E. Munroe and **Clarence Hall**. Pp. 61, 9 plates, 12 figures.

No. 424. The Valuation of Public Coal Lands. The Value of Coal Land ; by **George H. Ashley**. Depth and Minimum Thickness of Beds as Limiting Factors in Valuation ; by **Cassius A. Fisher**. Pp. 75.

Water-Supply Papers.—No 233. Water Resources of the Blue Glass Region, Kentucky; by **George Charlton Matson**. With a chapter on the Quality of the Waters; by **Chase Palmer**. Pp. 223, 3 plates, 6 figures.

No. 236. The Quality of Surface Waters in the United States. Part I. Analyses of Waters East of the One Hundredth Meridian ; by **R. B. Dole**. Pp. 123.

No. 238. The Public Utility of Water Powers and their Governmental Regulation ; by **René Tavernier** and **Marshall O. Leighton**. Pp. 161.

2. *Canada Department of Mines.* **Geological Survey Branch, R. W. Brock**, Director.—The following publications of the Survey have been recently received :

No. 973. Catalogue of Canadian Birds ; by **John Macoun** and **James M. Macoun**. Pp. viii, 761, with index.

Nos. 980, 1081. Reports on a portion of Algoma and Thunder Bay Districts, Ontario ; by **W. J. Wilson**. Pp. 49, 6 plates. Report on the Region Lying North of Lake Superior, between the Pic and Nipigon Rivers, Ontario; by **W. H. Collins**. Pp. 24.

No. 1035. The Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia ; by **D. B. Dowling**. Pp. 111, 11 plates, 1 map.

No. 1050. The Whitehorse Copper Belt, Yukon Territory; by **R. G. McConnell**. Pp. 63, 2 figures, and maps.

No. 1059. A Geological Reconnaissance of the Region traversed by the Transcontinental Railway between Lake Nipigon and Clay Lake, Ontario ; by **W. H. Collins**. Pp. 67, 2 plates, 1 diagram.

No. 1073. Catalogue of Publications of the Geological Survey, Canada. (Revised to January 1, 1909.) Pp. 181.

No. 1085. A Descriptive Sketch of the Geology and Economic Minerals of Canada; by **G. A. Young**. Introduction by **R. W. Brock**. Pp. 151, 82 plates, 2 maps.

Mines Branch.—**Eugene Haanel**, Director.—No. 23. Report on the Iron Ore Deposit along the Ottawa (Quebec side) and Gatineau Rivers; by **Fritz Cirkel**. Pp. vii, 147, 5 plates, 15 figures, 2 maps.

No. 62. Preliminary Report on the Mineral Production of Canada during the calendar year 1909; prepared by **John McLeish**. Pp. 18.

Special reports (Nos. 42–46) have also been issued on the production for the calendar years of 1907–08 of the following : iron and steel; chromite ; asbestos; coal, coke, and peat ; natural gas and petroleum.

Nos. 55 (Mines) and 1107 (Geologic Survey). Joint Report on the Bituminous or Oil-Shales of New Brunswick and Nova Scotia; also on the Oil-Shale Industry of Scotland. Part I, Economics; Part II, Geology; by R. W. Ells. Pp. 75, 15 plates, 6 figures.

3. *Kilauea and Mauna Loa, Hawaiian Volcanoes;* by Wm. T. Brigham, Mem. Bernice Pauahi Bishop Mus., vol. ii, No. 4. Pp. 222, 4°, 67 plates, 143 figs. Honolulu, 1909.—The author states in the beginning of his work that it is mainly for the purpose of presenting his studies, which have continued for nearly half a century, on the Hawaiian volcanoes, and thus supplying a collection of material which may be used by students of vulcanology; he modestly disclaims any attempt to solve by theorizing the deeper problems of this science, the source of volcanic heat and energy; in short, the cause of volcanic action. The work is thus mainly a record of observations of volcanic phenomena, and the writer has compiled so largely from the writings of other observers in this region, that the whole forms practically an historical account, in considerable detail, of the activity displayed here during the past fifty years. Particularly valuable in this connection are the various maps showing the changes which have taken place from time to time in the different craters. Much of the work, entirely aside from the standpoint of its being a collection of recorded observations, is very interesting reading, and the author's personal knowledge has enabled him to correct a number of errors, which at one time or another have crept into various publications on the volcanic phenomena of the islands.

The volume is well printed and bound, and embellished with a large number of half-tone cuts and plates from photographs, which greatly enhance its value and interest; the only criticism which might be offered in this connection is, that had a different kind of paper been employed, the half-tone cuts would have given much better results. The work as a whole is a very useful addition to the literature of vulcanology. L. V. P.

4. *Deviations from the Normal Order of Crystallization in Granite.*—Mackie, in an article entitled "Micropegmatites in Granite," gives the results of a study of a number of Scotch granites in which deviations from the usually assumed order of crystallization of the minerals occur. While ostensibly a study of various types of micropegmatite, its chief interest consists in the discussion of the order of crystallization and the explanations devised to account for irregularities. He finds in granite that quartz is the most aberrant mineral, its occurrence in abnormal position being equal to orthoclase and plagioclase together, and there are two maxima of this, one in the hornblende of hornblendic rocks, the other in the orthoclase of the more acid rocks. He explains this by supposing that in the molten solution the liquid hornblende is able to keep a certain amount of silica (or quartz) dissolved, but when the hornblende crystallizes this is also forced to crystallize; later the rest of the quartz would

appear in normal position. By thus considering the various solubilities of the different minerals in one another, the solvent action of contained water, and rises of temperature and resolution occasioned by successive crystallization, he is able to devise a scheme which will account for abnormalities in the order of appearance. In connection with this the reviewer would point out that it has scarcely been shown as yet that hornblende, as such, can exist in the molten solution ; the trend of investigation, indeed, tends to prove that the mineral molecules existent in the magma are of much simpler composition, and it seems probable that hornblende comes into being only in the act of crystallization.—*Trans. Edinb. Geol. Soc.*, ix, pt. iv, 247, 1909. L. V. P.

5. *New Occurrence of Lujavrite.*—The very rare and remarkable rock lujavrite was first found and named by W. Ramsay, from its occurrence at Lujavr Urt in the Kola Peninsula, Russian Lapland. It has been subsequently described by Ussing from southern Greenland. A new locality is now announced by H. A. **Brouwer** from Pilandsberg in the Transvaal. Like the two former occurrences, it consists of very flattened alkalic feldspars intermingled with nephelite and eudialyte and is pegged through with acicular aegirite. It also contains the associated rare minerals astrophyllite, mosandrite and låvenite. The eudialyte is apt to be changed into catapleiite, while considerable quantities of secondary pectolite are present. The following analyses of two varieties of the rock are by F. Pisani :

	SiO_2	TiO_2	ZrO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	
I	52·35	0·59	0·39	14·11	7·98	2·17	0·66	4·65	9·30	2·78	3·20	= 100·30
II	51·35	2·75	0·54	11·45	9·40	2·41	0·54	3·27	10·80	2·52	3·20	= 99·48

The total includes in I, $MnO = 0·62$ and $CO_2 = 1·50$; in II, $MnO = 1·25$. These correspond closely with the analyses of the Kola and Greenland rocks. It may be also mentioned that rocks resembling lujavrite have been described by Lacroix as a marginal facies of nephelite syenite from the Los Islands, French Guinea. The association with nephelite syenites occurs also with the lujavrites previously mentioned.— *Comptes Rendus*, Nov. 29, 1909. L. V. P.

6. *The Mercury Minerals from Terlingua, Texas.*—The remarkable minerals from Terlingua, several of them new, were described by Moses in 1903 (this Journal, vol. xvi, 253) ; later a preliminary account of their chemical examination was given by **Hillebrand** and **Schaller** (vol. xxiv, 259, 1907). The latter authors have now published their complete results in Bulletin 405 of the U. S. Geographical Survey. Many points of interest are brought out, particularly the remarkable complexity of the crystallization of the new species: thus montroydite is shown to have 56 forms, terlinguaite 134 forms, and even the isometric eglestonite 20 forms.

7. *The Rochester Collection of Meteorites; Descriptive List of Specimens;* by **Kenneth S. Howard.** Pp. 28, with 2 plates. Rochester, 1909.—The Rochester collection of meteorites, of which a catalogue has been recently published, contains a total of 234 falls, represented by 267 specimens: these include 89 siderites, 19 siderolites and 126 aerolites. A large part of the material was accumulated by the late Professor Henry A. Ward as duplicates in the course of his labors in bringing together the Ward-Coonley meteorite collection. Many fine individual specimens are noted in the catalogue, the collection being particularly rich in the irons, two-thirds of which weigh over 100 grams each.

8. *A new Meteorite from Georgia.*—A new meteoric stone has been recently described by **G. P. Merrill** from Thomson, McDuffie county, Georgia. It was found on October 15, 1888, but has been in private hands and its existence has only now been made public. Its present weight is 218 grams and could not have been greater originally than 250 grams; it is largely covered with a black crust. The specific gravity is 3·51 and a polished surface shows a light gray ground resolved with a lens into a compact mass of gray chondrules, with small particles of metallic iron and iron sulphide. It is somwhat similar to the Möcs meteorite.—*Smithsonian Misc. Conts.*, lii, pp. 473–476, 2 plates.

III. Miscellaneous Scientific Intelligence.

1. *Carnegie Institution of Washington.*—Recent publications of the Carnagie Institution are noted in the following list (continued from vol. xxviii, p. 564):

No. 74. The Vulgate Version of the Arthurian Romances, edited from Manuscripts in the British Museum; by **H. Oskar Sommer.** Vol. I, Lestoire del Saint Graal. Pp. xxxii, 296. Vol. II, Lestoire de Merlin. Pp. 466.

No. 85 (Kentucky). Index of Economic Material in Documents of the States of the United States. Kentucky, 1792–1904. Prepared for the Department of Economics and Sociology of the Carnegie Institution of Washington; by **Adelaide R. Hasse.** Pp. 452.

No. 100. The Seal Cylinders of Western Asia; by **Williams Hayes Ward.** Pp. xxix, 428, 1315 illustrations.

No. 108. The Atrium Vestæ; by **Esther Boise Van Deman.** Pp. ix, 47, frontispiece, 10 plates and plans A–F, showing walls of various periods.

No. 116.—The Differentiation and Specificity of corresponding Proteins and other vital Substances in relation to Biological Classification and Organic Evolution: The Crystallography of Hemoglobins; by **Edward Tyson Reichert**, and **Amos Peaslee Brown.** Pp. ix, 338, 100 plates and 56 tables.

No. 121. Inheritance of Characteristics in Domestic Fowl; by **Charles B. Davenport.** Pp. iii, 100, with 12 colored plates.

2. *Publications of the Allegheny Observatory of the University of Pittsburgh.*—The following has been recently issued: Vol. I, No. 20. The Algol—Variable δ Libræ. Pp. 123–134.

New Circulars.

84: **Eighth Mineral List:** A descriptive list of new arrivals, rare and showy minerals.

85: **Minerals for Sale by Weight:** Price list of minerals for blowpipe and laboratory work.

86: **Minerals and Rocks for Working Collections:** List of common minerals and rocks for study specimens; prices from 1½ cents up.

Catalogue 26: Biological Supplies: New illustrated price list of material for dissection; study and display specimens; special dissections; models, etc. *Sixth edition.*

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Prof. W. G. Farlow.

XXIX. MAY, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

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FOURTH SERIES

VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

No. 173—MAY, 1910.

NEW HAVEN, CONNECTICUT.

1910.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXII.—*Contributions to the Geology of the Grand Canyon, Arizona.—The Geology of the Shinumo Area;* by L. F. Noble.

Part I.

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Introduction.
    Location.
    Field Work.
    Literature.
    Acknowledgments.
    Geologic Nomenclature.
Topography, Climate and Vegetation.
General Geology.
    Archean—Vishnu Schist.
    Name.
    Distribution in the Kaibab Division.
    Occurrence and Distribution in the Shinumo Area.
    Lithology.
    Origin.
    Age and Correlation.
Bibliography.

Preface.

Exposures of unaltered pre-Cambrian sediments are of great interest to the geologist in any part of the world. Especially is this true in the Grand Canyon of Arizona, where the certainty of stratigraphic position and completeness of exposure are almost without a parallel, and where the spectacular nature of the occurrence partakes of the stupendous and fantastic scenery of that mighty gorge, from the spell of which the observer is never entirely free. During a pleasure trip in the Grand Canyon region in January, 1908, in company with Professor H. E. Gregory of Yale and others, the writer chanced to visit a hitherto undescribed exposure of these rocks on the

Colorado River at the foot of Bass Trail. Although only a few hours were spent in the vicinity, the diagrammatic simplicity with which the structural relations were revealed was such that the interest could be immediately realized. In the summer of that year the writer returned with the intention of making a detailed study of these pre-Cambrian rocks. He speedily found that the interest in this part of the Grand Canyon did not end with the study of the pre-Cambrian alone: it was found that the line of displacement of the West Kaibab fault which runs into the Grand Canyon at this point was itself a remarkable structural feature and worthy of considerable attention; that the entire Paleozoic section of the canyon wall was here, as elsewhere, undescribed in absolute detail; and finally that there were problems of physiographic interest in the Grand Canyon region the ultimate solution of which could be greatly helped by a detailed study at this point. It was therefore decided to extend the work to a complete areal study of the region, including for this purpose the greater part of the new Shinumo topographic sheet of the United States Geological Survey. This report, accompanied by an atlas containing the geologic maps, sections, and plates, was presented to the faculty of the Graduate Department of Yale University in June, 1909, as a thesis in partial fulfillment of the requirements for the degree of Ph.D., under the title of "The Geology of the Shinumo Area, Grand Canyon, Arizona."

It is intended to present the substance of the thesis in two or more articles in this Journal. The entire report is to be published *in extenso* at a later date as a Bulletin of the United States Geological Survey. For this reason, as well as because of the large scale and elaborate nature, the geologic map, sections, and plates will not be published here.

The first article will be presented in two parts. Part I, now published, comprises a general introductory description of the Shinumo area and deals with the basement rocks of the Archean. Part II, to follow in a later number, will be devoted to the Algonkian rocks of the Grand Canyon series and will include a map showing the distribution of the Vishnu and Grand Canyon series in the Grand Canyon.

It is also proposed to devote a later article or articles to the Paleozoic section of the canyon wall; to a structural study of the area, including both the pre-Cambrian and later structure and a study of the displacements on the line of the West Kaibab fault; and finally to features of physiographic interest in the area,—such as the drainage system of the plateaus and the origin of the Esplanade and Tonto platforms.

INTRODUCTION.

Location and geography.—The area studied lies in Coconino County in the northern part of Arizona in what is known as the Plateau Province of the Territory. It is inclosed between meridians 112° 25′ and 112° 15′ and parallels 36° 20′ and 36° 05′, and includes about 150 square miles. It comprises rather more than the eastern half of the area of the Shinumo topographic sheet of the United States Geological Survey.

The greater part of the area lies within the depths of the Grand Canyon and includes the Shinumo Amphitheater, which is the largest of the great amphitheaters in the Kaibab division. The eastern and northern parts of the area include that part of the "mainland" north of the canyon which forms the immediate rim of the Shinumo Amphitheater, reaching from the promotory of Point Sublime on the east to the Muav Saddle on the west; this northern mainland is a part of the Kaibab Plateau. The northwestern part of the area includes the surface of Powell Plateau, a great butte, or "island," lying athwart the course of the Grand Canyon. The southwest corner includes a part of the southern "mainland" which culminates in the great promontory known as Havasupai Point; this southern mainland belongs to the Coconino Plateau.

About a mile west of Havasupai Point is situated Bass Camp, the only habitation in the area. The camp was established by Mr. W. W. Bass some twenty-five years ago to accommodate the tourist traffic. From this point a trail was constructed to the river, which was crossed by boat at times of low water. A permanent camp was established in the bottom of the canyon on the north side of the river about a mile up Shinumo Creek, where an irrigated garden was made upon the site of an ancient one cultivated by the prehistoric inhabitants of the region. Later a trail was constructed up Muav Canyon to the north rim, by means of which access may be had to points on the Kaibab Plateau and the settlements in Southern Utah. Recently deposits of copper and asbestos have been discovered by Mr. Bass in the depths of the canyon, to which he has constructed additional trails. In March, 1908, three wire cables were suspended across the granite gorge at the foot of Bass Trail. On these cables travels a wire car, so that at the present time the Colorado River may be crossed at this point regardless of high water. Bass Camp is most easily reached by wagon road from Bass Station on the Grand Canyon branch of the Sante Fe Railroad, a distance of 20 miles southeast; or from the El Tovar Hotel at the terminus of the railroad 25 miles east. Another road leads 20 miles southwest to the rim of Cataract Canyon, into which a trail leads down to the Supai

Indian village. Roads also lead to the towns of Williams and Ash Fork, about 60 miles respectively south and southwest.

Field Work.—The geological field work upon which the thesis is based was begun upon the 23d of August, 1908, and ended upon the 12th day of December of the same year. The greater part of the work was done from a permanent camp on the Shinumo, which served as a base of operations for studying all the region in the greater depths of the canyon. Two trips were made to the north rim. The first was made in September and the second in November. Each trip lasted a week. Camp was established in the Muav Saddle and excursions were made from there over the surface of Powell Plateau and over the Kaibab mainland as far as the head of the Shinumo Amphitheater. The writer was accompanied on these occasions, as well as during his stay in camp on the Shinumo, by Mr. John Walthenberg as guide, whose detailed knowledge of the region and whose assistance in other ways were invaluable. The work in the southern part of the area was done from Bass Camp, from which point excursions were made over the Coconino Plateau and into the upper part of the canyon.

Literature.—Two references to the geology of the area are to be found in geological literature:

Captain Dutton in his monograph entitled "The Tertiary History of the Grand Canyon District" (Dutton, *a*) describes most fully and charmingly the geology of the north rim in this section of the Grand Canyon. In Chapter VII he describes the surface features and scenery of the Kaibab Plateau in the vicinity of Point Sublime. Chapter VIII is devoted to the panorama disclosed from Point Sublime, while Chapter IX describes the walls of the amphitheaters of the north side in detail. The Muav Saddle and Powell Plateau are described on pp. 162–167, and the Shinumo Amphitheater on pp. 167–174. His work, however, did not extend into the depths of the canyon.

Mr. J. S. Diller of the United States Geological Survey describes in his report on the production of asbestos in "Mineral Resources for 1907" (Diller, *a*) the deposits of asbestos occurring in the Algonkian sediments of this area near Bass Ferry. This is the only reference in the literature to the presence of Algonkian strata in this part of the Grand Canyon.

Acknowledgments.—In 1901 Mr. Charles D. Walcott and Mr. G. K. Gilbert spent several days at Mr. Bass's camp on the Shinumo and at that time worked out the structure of the pre-Cambrian sediments, which Mr. Walcott correlated with the section described by him in Unkar Valley (Walcott, *a*, *b*, *c*, *d*, and *e*). His notes, however, are unpublished, and it is due to his kindness and courtesy that the writer is enabled to present the first description of the area. To Mr. Walcott the writer is also indebted for the identification of Cambrian fossils, for a list of the Cambrian fossils found in the region, and for assistance in interpreting the stratigraphy.

To Professor Joseph Barrell, to Professor Charles Schuchert, and to Professor Louis V. Pirsson, all of Yale University, the most sincere thanks are due for continued interest and advice during all stages of the work. To Mr. W. W. Bass the writer is indebted for material assistance and guidance during his work in the field.

Geologic Nomenclature.—The geologic names employed in this article are revised names recently authorized by the United States Geological Survey, with the exception of those of the Cambrian, which as yet have not been formally revised. The first table below gives the rock formations of the Shinumo area in terms of the revised terminology, while the second table gives the equivalent of the newer in the older nomenclature.

I.

Geologic column of the Shinumo Area.

System	Series	Group	Formation
Carboniferous	Pennsylvanian	Aubrey	Kaibab limestone Coconino sandstone Supai formation
	Pennsylvanian and Mississippian	Redwall	Redwall limestone
(Unconformity of erosion without uniformity of dip)			
Cambrian	Acadian (and Saratogan?)	Tonto	"Marbled limestone" "Tonto shale" "Tonto sandstone"
(Great angular unconformity)			
Algonkian	Grand Canyon	Unkar	
(Greatest angular unconformity)			
Archean	Vishnu		

II.

Revised Nomenclature	*Classic Nomenclature of the reports of Dutton, Gilbert, and Walcott.*	
Formation	Formation	Group
Kaibab limestone	Cherty limestone	Upper Aubrey
Coconino sandstone	Cross-bedded sandstone	
Supai formation	Lower Aubrey sandstone	Lower Aubrey
Redwall limestone	Redwall limestone	Redwall
"Marbled limestone"	Marbled limestone	Upper Tonto
"Tonto shale"	Tonto shale	
"Tonto sandstone"	Tonto sandstone	Lower Tonto

Topography, Climate, and Vegetation.

The surfaces of the plateaus in the Shinumo area through which the pathway of the Grand Canyon is trenched are everywhere developed at the same horizon on the highest member of the Paleozoic series occurring in the Canyon wall and known as the Kaibab limestone, the Mesozoic and Tertiary formations having been stripped back to the terraces of southern Utah.

The surface of the southern, or Coconino, plateau slopes to the southwest away from the canyon rim at the rate of about 200 feet to the mile. The drainage system of the plateau surface consists of a series of mature, open-floored valleys with gently sloping sides, which contain no living streams. These valleys trend southwesterly away from the canyon rim with the slope of the plateau surface and drain into the broad, shallow synclinal basin occupied by Cataract Canyon. In tracing one of these mature valleys toward its head, it is a common thing to find it truncated as a hanging valley by the wall of the Grand Canyon. So general is this phenomenon, that the stranger who loses his way on the southern plateau has only to keep in mind that if he follow any valley far enough headward he will come out upon the rim of the Grand Canyon.

The surface of the northern, or Kaibab, plateau is in every respect similar to that of the Coconino. The same system of mature valleys covers its surface, which slopes southwesterly to the rim of the canyon. The only difference is that the surface drainage runs into the Grand Canyon instead of away from it. Neither plateau surface contains a living stream.

Powell Plateau may be regarded as a dismembered part of the Kaibab. Its surface is developed at the same horizon on the Kaibab limestone, slopes southwesterly at the rate of 900 feet in five miles, and contains the same mature drainage system. It is substantially a great island, surrounded on three sides by mile-deep canyons, and isolated from the mainland by erosion in the line of displacement of the West Kaibab fault. The gap that separates Powell Plateau from the mainland is called the Muav Saddle, and is notched 800 feet below the surface of the plateaus. No more striking topographic contrast can be imagined than that between the mature drainage systems of the plateaus and the youthful topography within the deep-trenched canyon.

The strata of the Paleozoic rock system within the area dip gently and almost uniformly to the southwest at the rate of about 200 feet to the mile, and the surfaces of the plateaus are everywhere accordant with the rock structure. A slight local interruption occurs where the line of the West Kaibab fault crosses the area, along which the strata are flexed into a monocline dipping sharply northeastward. A few minor flexures cross the area in a northwesterly direction; all dip to the southwest and are hardly more than gentle swells upon the general warping.

The Shinumo Area is a critical area for the study of the topography within the canyon itself. It is here that the topography undergoes a transition from the profile which is characteristic of the Kaibab division to that which is characteristic of the Kanab.

In the eastern, or Kaibab, division of the canyon, the descent of the wall is unusually abrupt throughout the entire Paleozoic rock series. The only bench or terrace of any extent or definition is that which is developed near the bottom of the canyon upon the summit of the basal sandstone of the Tonto group. The bench is known as the Tonto platform; in it is cut an inner gorge, in which the river flows upon the basement schists of the Archean. The platform averages a mile in width on either side of the canyon, and is so well defined that one may travel upon it throughout the length of the Kaibab division. In the next western, or Kanab, division of the canyon the lower terrace has disappeared. Instead, a wide bench is opened out upon the summit of the hard red sandstones of the Supai formation of the Aubrey group, about a thousand feet below the level of the canyon rim. This bench forms a broad level platform averaging two miles in width on either side of the canyon, and has been named by Dutton the "Esplanade." Through it is cut a deep and narrow inner gorge, at the bottom of which flows the river.

The topography of the Kaibab division is characterized by a much greater dissection than that of the Kanab; great amphitheaters are eroded back into the north wall, thronged with buttes and outliers fashioned out of every formation of the Paleozoic rock series and trenched by a multitude of side gorges. The topography of the Kanab division is very simple, consisting only of a broad outer canyon in which is cut the inner gorge; the great dissection which makes the fantastic scenery of the Kaibab division is entirely lacking.

Eastward from Havasupai Point in the Shinumo area the topography in the canyon is that which is characteristic of the Kaibab division. Westward, however, the upper platform or "Esplanade" begins to appear. The Shinumo amphitheater, which occupies the greater part of the area to be described, presents a combination of both types of topography; the great dissection and the presence of the Tonto platform are features characteristic of the Kaibab division, but the Esplanade characteristic of the Kanab division is developed to quite an equal extent upon the upper surface of the Supai sandstone. In the western part of the area the Tonto platform fades out, the river closes in a deep inner gorge in the Esplanade, and the profile of the canyon becomes that of the Kanab division,—the view of the canyon westward from Bass Camp discloses a broad expanse of Esplanade for fifteen miles, through which the inner gorge sweeps in two great meanders almost from wall to wall. In the center of the Shinumo area the Esplanade is rather more dissected than in the Kanab division farther west, but its identity as a topographic feature is already well established.

The floors of the Esplanade and Tonto platforms, like the surfaces of the plateaus, are structural surfaces developed everywhere at the same horizon on the underlying formation. In conformity with the dip of the rock system they likewise slope to the southwest at the rate of about 200 feet to the mile.

Another topographic contrast is presented in the difference in dissection of the two sides of the Grand Canyon, a feature which is characteristic of the entire pathway through the Kaibab. The north rim lies three times as far back from the river as the south rim; the great amphitheaters with their limiting promonotories extending far into the canyon, the buttes and temples, and the deep lateral gorges all belong to the north side of the canyon. The south wall presents a simple aspect: the side gorges rarely extend back into the rim of the canyon, there are few buttes and outliers, and the great amphitheaters are wholly lacking. Compared with the fantastic topography of the north side, the scenic effect of the south wall is precipitous and somber.

The Colorado River enters the area in the southeast corner, flows northwestwardly to the center of the area, and turns sharply west at the point where it is joined by the Shinumo. The Shinumo is the only living tributary in the area, and is the master stream that drains the Shinumo amphitheater of the north wall. It is a stream of clear water of the same order of magnitude as Bright Angel Creek twenty miles east, and is in striking contrast to the muddy Colorado.

The topography of the Shinumo amphitheater, besides presenting an equal development of both the Esplanade and Tonto platforms, is remarkable in another way. In the other great amphitheaters of the Kaibab division the master gorges trend to the southwest; the tributary gorges trend in the same general direction and lateral gorges perpendicular to the main axes of the amphitheaters are of minor development. In the Shinumo amphitheater the lateral gorges have become the dominant feature, so that the main axis of the amphitheater trends to the northwest at right angles to the course of the master stream and parallel to the course of the Colorado River. The greatest lateral gorge extends entirely across the Shinumo amphitheater from Point Sublime on the southeast to the Muav Saddle on the northwest. Only a mile of this lateral gorge is occupied by the master stream of the Shinumo; the remainder is occupied by two small intermittent streams. The western part of the gorge which extends from the Muav Saddle to Shinumo Creek is drained by Muav Creek and is called the "Muav Canyon"; the eastern part extending from the Shinumo to Point Sublime is drained by Flint Creek and has no local name. The entire lateral gorge will be referred to as the "Muav-Flint Creek Canyon." This remarkable linear depression is situated upon the line of the West Kaibab fault and has been conditioned by erosion in that line of fracture. Two smaller lateral gorges cross the heart of the amphitheater parallel to the "Muav-Flint Creek Canyon"; these are situated upon minor lines of fracture.

It may be noted here that Tapeats amphitheater to the westward, in the Kanab division of the canyon, is characterized by similar topographic features where it is crossed by the West Kaibab fault.

In general the surface of the Kaibab plateau at the rim of the canyon is about 1000 feet higher than that of the Coconino plateau directly opposite. But since the surfaces of the plateaus and of the platforms within the canyon are structural surfaces, elevations diminish progressively southwestward in all parts of the area in accordance with the dip of the underlying rock structure. For example: the elevation of the Kaibab Plateau at the head of the Shinumo amphitheater is 8000 feet; at the end of the promontory of Point Sublime, four miles southward, it is 7500 feet. The elevation of the Coconino Plateau at the end of Havasupai Point is 6750 feet; at Bass Camp, a mile southwestward, 6652 feet. The eastern end of Powell Plateau at Dutton Point is 7555 feet; the western end is 6600 feet. Within the canyon the elevation of the Esplanade platform on the north side of the river below Point Sublime is 6250 feet; on the south side of the river below Bass Camp, 5400 feet. In the eastern part of the area the Tonto platform is 3500 feet; in the western part, 2700 feet.

The elevation of the surface of the Colorado River where it enters the area on the east is 2250 feet; where it leaves the area on the west, 2150 feet,—a drop of 100 feet in 10 miles. The river at Bass Ferry is 300 feet wide and 50 feet deep, with a rise of 40 feet at time of high water.

The greatest drops in the shortest linear distance in the area are at Dutton Point, where a drop of 5355 feet to the river is accomplished in a distance of three miles; and at Havasupai

Point, where a drop of 4500 feet is accomplished in a distance of a mile and a half. The latter drop is not equaled elsewhere in the Grand Canyon.

The width of the Grand Canyon in the Shinumo area from Bass Camp to Dutton Point is seven miles; from Bass Camp to the head of the Shinumo Amphitheater it is twelve miles; from Havasupai Point to Point Sublime it is five and one-half miles. The latter is the minimum width of the Grand Canyon in the Kaibab division. Even at this, the narrowest point, the width is over five times the depth.

The differences of climate to be found within the Shinumo area are remarkable. The range in climate between the Kaibab Plateau on the north rim and the bottom of the canyon is as great as that between the mountains of Colorado and the Mojave Desert. The winters on the Kaibab are extremely severe: from November to April the snow lies deep in the woods, often accumulating to a depth of ten feet; even in midsummer the nights are chilly and days delightfully cool. Within the canyon, however, the snow rarely falls below the level of the Esplanade, while on the Tonto platform a fall of snow is practically unknown. The winters in the depths of the canyon are mild, and freezing temperatures are rare. From April to October the entire canyon below the Red Wall concentrates the solar heat, transforming it into a veritable oven; all day the bare rocks absorb the heat of the sun, becoming so hot as to burn the hand; by nightfall the wind becomes a furnace blast, and until after midnight the rocks radiate their heat, feeding the hot wind, which blows without ceasing. The effect of the heat, however, is not enervating, for the dryness of the warm wind evaporates all moisture from the body and keeps it cool. The climate of the southern, or Coconino, Plateau at Bass Camp is characterized by more open winters than the Kaibab, as well as by warmer summers: the snow in winter rarely accumulates on the surface to a great depth, and as a rule vanishes entirely within three days after a storm; in summer the days are unpleasantly hot.

The climate of the Kaibab Plateau is decidedly moist, the precipitation being probably twice as great as that received upon the Coconino Plateau across the canyon; this is chiefly due to its greater altitude. In winter the precipitation takes the form of snow; in summer it comes in the form of showers, which occur through the afternoon and evening. Looking across the canyon from Bass Camp on the south rim, almost any summer evening one may see storm after storm sweeping over the Kaibab surface, usually accompanied by violent electrical display, while the sky overhead and to the westward over the Kanab Desert remains as clear as crystal. Another phenomenon that contributes to the greater rainfall of the north rim seems to be the presence of the Grand Canyon itself: after every general storm that visits both sides of the canyon alike, there follows on the south rim a day of clearing; but the clouds that rise out of the canyon after the storm sweep back over the north wall and re-precipitate on the Kaibab surface; these secondary storms almost never return over the south rim. The climate of the Coconino Plateau in the area is semi-arid; often no rain will fall for a month at a time. The precipitation is greatest in the winter months and in the month of July. Within the canyon much of the rainfall evaporates before it reaches the greater depths, so that the climate of the lower part of the canyon is more arid than that of the southern plateau.

Powell Plateau, whose higher eastern portion has an altitude equal to that of the Kaibab rim, and whese lower western portion has an altitude equal to that of the Coconino, has an intermediate climate. Its situation as an island in the canyon serves to moderate the cold in winter, for the warm air, rising out of the deep canyons that surround it, acts as a radiator: the snow does not accumulate so deeply on the eastern end as on the Kaibab; and on the western end does not accumulate at all. Its surface is a resort in winter for the game and wild horses that are driven out of the Kaibab by the snow. Its exposed position subjects it to violent gales of wind at all times of the year. The higher eastern end receives an abundant rainfall, while the lower western end is semi-arid.

The variation of the flora in the Shinumo area is as great as that of the climate. The surface of the Kaibab Plateau is covered with a magnificent open forest of yellow pine; the trees grow large and far apart and the ground is free from undergrowth, giving its surface the aspect of a great park; Englemann spruces grow on the north slopes of the washes, and cottonwoods, aspens, and scrub oaks in their bottoms; a minor flora of flowering plants, exceedingly rich in species, covers the floor of the forest. The flora of the plateau surface of the south rim of the canyon differs completely from that of the Kaibab; it is covered with a forest of gnarled and stunted trees of juniper and piñon, with here and there a buck-brush bush; the trees never form thickets, but grow wide apart; while the open stretches are covered with sage brush and mormon tea, with occasional cactus, mescal, and plants of the century family. This difference between the floras of the north and south rim is due to the differences in precipitation and temperature, which vary directly with the altitude. For this reason the floras of the plateaus furnish an almost unfailing index of the elevation. This is beautifully shown on the southwestward-sloping surface of Powell Plateau, the whole eastern half of which lies at an elevation of from 7000 to 7500 feet and is covered with the open pine forest characteristic of the Kaibab. At about 7000 feet the character of the flora changes, and passes into the gnarled and stunted forests of juniper and piñon characteristic of the southern plateau across the canyon.

Within the canyon itself the variation in the flora is just as great, and is again an index of the elevation.

The flora of the Esplanade platform, a thousand feet below the south rim, consists of stunted bushes of juniper and piñon with greasewood as the ground bush in place of the sagebrush of the Coconino Plateau. The cactus, mescal, and plants of the century family are present in greater abundance than on the plateau, but in less abundance and in more stunted development than in the bottom of the canyon. This is due to the fact that the Esplanade level is within reach of the winter snows and frosts.

The flora of the Tonto platform, three thousand feet below the south rim, and of all the interior of the canyon below the Red Wall, is the flora of a hot and arid desert in its most characteristic form. The dominant plants are the greasewood bush, the mormon tea, and the cactus. The mescal and the plants of the century family here attain their greatest development and size. The cacti are particularly rich in species. Every plant in the flora is either prickly or aromatic; leaf surfaces are reduced to a minimum; devices for storing water attain the greatest perfection; and the dominant color is a somber gray. The somber colors and the reduction of leaf surface are apt to deceive the observer, both in regard to the richness of the flora in species and the abundance of plant life, which is far greater than one would suspect. The only tree is the screw-mesquite, which grows in the beds of those washes that contain living or intermittent streams.

The vegetation in the bottoms of those canyons of the north side in the Shinumo Amphitheater which contain living streams is beautiful beyond description, and in refreshing contrast to the desert flora of the Tonto platform. Tall cottonwoods grow in the lower canyons; the walls are hung with maidenhair fern in the shady places; and willow thickets border the stream. Grass grows on the banks where there is soil. Higher up in the canyons, oaks, maples, and other deciduous trees come in, and often beds of tall rushes. The most characteristic bush of these upper north-side canyons is the manzanita, which does not grow on the south side of the Grand Canyon.

GENERAL GEOLOGY.

ARCHEAN— *Vishnu Schist.*

Name.—The name "Vishnu Terrane" has been given by Walcott (Walcott, c) to the fundamental crystalline complex of the Grand Canyon region that underlies the unaltered sedimentary rocks of Algonkian age, and is separated from them, as well as from the overlying Cambrian, by a profound unconformity. The type locality is situated on the Colorado River thirty miles east of the Shinumo area at the base of one of the great buttes called "Vishnu's Temple," from which he derives the name.

Distribution in the Kaibab division.—The rocks of the Vishnu series are exposed continuously for a distance of over forty miles within the Kaibab division of the Grand Canyon in the bed of the Colorado River and in the walls of its gorge which is cut beneath the Tonto platform. The Shinumo area is at the western end of this long exposure. The eastern limit of the exposure is determined by the appearance of great thicknesses of overlying strata of the Grand Canyon series dipping northeastward into the bed of the river, in the classic locality described by Walcott. The western limit of the exposure is likewise defined by a structural cause: three miles west of the Shinumo area a southward bend of the river causes it to flow parallel to the gentle southwestward dip of the Paleozoic rock system of the canyon wall, carrying the bed of the stream up out of the schists and into the basal Tonto sandstone of the Cambrian.

Occurrence and distribution in the Shinumo area.—The Vishnu schists are exposed for a distance of three miles in the gorge of the Muav-Flint Creek Canyon. They are exposed in the bed of the Colorado river throughout its course across the Shinumo area. Along the south bank of the river for a distance of four miles, and along the north bank for a distance of seven miles, in the eastern half of the area, sediments of the Grand Canyon series intervene between the Vishnu schists and the Tonto sandstone of the basal Cambrian. Elsewhere the schists are exposed without break in the walls of the river gorge beneath the Tonto sandstone.

No detailed study of these rocks was made in the Shinumo area beyond the general location and determination of the various types represented, since the limited extent of the exposures precludes the possibility of unraveling any general Archean structure from the study of this area alone. They are here a metamorphic complex of quartz, mica, and hornblende schists, invaded by a batholithic mass of quartz-diorite, and injected by veins of pegmatite and aplite.

Five main types of rock are found in this complex within the area:

The first type is a quartz schist, with graduations into mica schist. It comprises the greater part of the Vishnu schists that are exposed in the gorge of the Colorado River west of the cable crossing at Bass Ferry. It is also exposed in the bed of Muav Canyon, and in the bed of Flint Creek above the junction with the Shinumo.

The second type is a quartz schist with gradations into quartz-hornblende schist. It is exposed in that part of the Muav-Flint Creek Canyon that is occupied by the living stream of the Shinumo, grading both eastward and westward into the quartz-mica schist.

The third type is a hornblende schist. It occurs in one small outcrop about 200 feet wide, on the east side of "Fault wash," a dry wash which joins the Shinumo just below the mouth of Muav Canyon, and is sharply bounded on both sides by the quartz-mica schist.

The fourth type of rock is a quartz-diorite. So far as observed, it constitutes all of the Vishnu series of the Shinumo area that is exposed in the "granite gorge" of the Colorado River east of the cable crossing. Its western contact is well defined. The eastern limit of the exposure was not located.

The fifth type of rock is a granitic pegmatite which occurs in dikes that cut all the rock types of the Vishnu. These dikes occur in two generations. The older generation is folded with the schists. The younger generation occurs in a great network or mesh of dikes cutting both the quartz-diorite and the schists.

The Vishnu schists have a typical schistose structure. The planes of schistosity have a dip that seldom departs greatly from the vertical. The dominant trend of the schistosity is northeasterly, but varies, from place to place. Locally, the schists are much twisted and contorted.

Lithology.—The less micaceous phase of the *quartz-mica schist* has a dark grey color with a greenish tinge. The cleavage is imperfect and the surfaces have a satin-like luster. The texture is fine-grained and the unaided eye can distinguish no mineral constituents except quartz. The microscope shows the rock to be composed almost entirely of fine interlocking grains of quartz, with occasional small flakes of white mica, arranged in parallel lines. In the extreme quartzose phase the amount of mica is almost negligible, just enough being present to impart a satin-like luster to the rock.

The micaceous phase of the schist has a slight grey color with either a pinkish or greenish tinge on the fresh fracture. Where the rock is weathered, the color becomes red. The cleavage is rather distinct. The texture ranges from fine to coarse. To the unaided eye both the quartz and mica are visible. Under the microscope the rock is seen to be composed of interlocking grains of quartz, with an almost equal amount of mica. The mica flakes are arranged in parallel lines. The greater part of the mica is muscovite, with occasional flakes of brown biotite.

Locally the schist is garnetiferous, and in one locality tourmaline was observed. All gradations between the quartzose and the micaceous phases occur, but in no instance does the mica exceed the quartz in quantity.

The *quartz-hornblende schist* is dark green in color. The cleavage is imperfect, and the texture fine-grained and uniform. The rock is dense and hard. The mineral constituents cannot usually be distinguished in the hand specimen without the aid of the lens. Under the microscope the rock is seen to consist of about equal proportions of quartz and green hornblende. The quartz is present in interlocking grains. The hornblende tends to form automorphic crystals whose longer axes have a roughly parallel arrangement. No other minerals were present in the slides examined. In some phases of the rock the quartz exceeds the hornblende in amount.

The *hornblende schist* is dark green in color. It is a soft rock, considerably disintegrated, and crumbling under the hammer. The texture is coarse granular. Megascopically the rock appears to consist almost entirely of dark green hornblende. No schistose structure is observable in the mass. The microscope shows the rock to consist almost wholly of large crystals of green hornblende in all stages of alteration. A small amount of interstitial quartz occurs. The quartz granules are strung out in a roughly parallel fashion. The rock is badly altered and the thin section is unsatisfactory.

The *quartz-diorite* found in the river gorge eastward from the cable crossing is a coarse-granular rock of typical granitic texture. It is a hard, resistant rock, which tends to weather into roughly angular blocks, a feature that distinguishes it in the mass from the exposures of the schists. The minerals visible to the unaided eye are white striated feldspar, dark hornblende, and glistening black biotite. The color of the rock is dark grey and the appearance is remarkably fresh. The texture is uniform throughout the exposures observed, and the rock is apparently without contact modifications. No tendency to gneissoid banding was observed.

Under the microscope it is seen to be a coarse-granular rock of granitic texture. The dominant mineral constituents are plagioclase and common hornblende. The plagioclase ranges from oligoclase to labradorite. Microcline, orthoclase, and quartz are present in about equal proportions, but their total amount does not equal that of the plagioclase. Brown biotite is present in somewhat less quantity than the hornblende. Titanite and magnetite occur as accessories. Occasionally the quartz is poikilitic in the orthoclase. The feldspathic and ferromagnesian minerals are present in about equal proportions. If it were not for the preponderance of the plagioclase the rock might be classed as a quartz-monzonite or grano-diorite. It is probably best classed as a quartz-diorite with a monzonitic aspect. The microscope reveals no cataclastic structure nor other evidence of dynamic action, and the minerals are fresh and unaltered.

The *pegmatites* are pink in color and usually very coarse in texture. They are composed chiefly of quartz and pink orthoclase. Some of the dikes carry large crystals of silvery-white mica. No other minerals were noted. The dikes usually exhibit the typical comb-structure inward from the walls and the graphic arrangement of the quartz and feldspar. Along the walls of some of the dikes the texture becomes aplitic.

Origin.—There is no clear evidence in the Shinumo area by which the original character of the schists of the Vishnu series can be determined. There is no evidence of a banding that can be clearly referred to original sedimentary bedding, nor is there evidence of any original clastic texture. The mineralogical composition, however, suggests a sedimentary origin for the quartz schists of the mica and hornblende type: either might have resulted from the regional metamorphism of an arkose sandstone or shale. According to the lesser or greater abundance of iron in the original sediments the rock would assume the mica or hornblende type of quartz schist. Certainly the great preponderance of quartz as a constituent of these rocks would seem to weigh against an igneous origin in the balance of probability. The causes operating to produce the schists in their present aspect are conceived to be the processes connected with regional metamorphism, namely, subsidence and deep burial, subsequent folding and mashing, and a slow recrystallization in process of time.

The original character of the *hornblende schist* described as occurring in a narrow outcrop between the schists is not clear. The fact that the rock consists of little else than hornblende suggests that it originally constituted an igneous rock of a basic type. The fact that the microscope discloses a schistose structure is evidence that the rock is at least earlier in age than the period of regional metamorphism that was responsible for the present structural and mineralogical character of the enclosing schists.

The origin of the *quartz-diorite* is reasonably clear. Since it is a coarse-granular, igneous rock of plutonic aspect occurring over a large area, clearly cutting the schists, and showing no textural modifications at the contact, it is concluded that it represents a deep-seated igneous invasion of considerable size, of the type known as a "batholith." Because of the unaltered character of the rock and the absence of any gneissoid or cataclastic structure, it is argued that the batholithic invasion took place at a time later than the period of regional metamorphism that produced the recrystallization and schistosity of the enclosing schists. The question may arise as to whether the invasion of the batholith was not of itself a partially operative cause in producing this recrystallization and schistosity. The field evidence is against such a conclusion: there is no gradation in the schist away from the contact, either in texture or in mineral composition, nor are the planes of schistosity parallel to the contact.

The *older pegmatite dikes* are folded intimately with the schists. Their injection may have either preceded or accompanied the regional metamorphism.

The *younger pegmatite dikes* cut both the schists and the quartz-diorite. Where they cut the schists they break cleanly across the schistosity. The injection of these dikes is the latest visible event in the igneous activity of Archean time within the area.

Age and correlation.—The rocks of the Vishnu series are rocks which, in the light of present knowledge, can only be conceived to have acquired their present character at great depths beneath the earth's surface in what is technically known as the "zone of flowage." It is therefore evident that the unconformity which separates them from the overlying Algonkian sediments of the Grand Canyon series represents a vast amount of erosion and the consequent lapse of an enormous interval of time,—an interval vastly greater even in events than that represented by the profound unconformity which separates the succeeding Grand Canyon series from the overlying Paleozoic. The Vishnu schists are therefore assigned to the Archean in the usage of the United States Geological Survey; but whether as a group or a complex is as yet undecided. It seems likely, as stated by Ransome (*a*, p. 21), that they are to be correlated with the Pinal Schist of the Globe and Bisbee regions, and "present somewhat different aspects of the fundamental crystalline complex of Arizona."

Up to the present time no detailed study of these rocks has been made in the Grand Canyon region, and their internal structural relations are unknown. It is not unlikely when such a study is made of their exposures in the Kaibab division of the canyon, in the Shivwits division to the west, and along the southwest border of the Plateau Province, that a general Archean structure may be unraveled and their relation to the fundamental complex of the southern part of the territory may be definitely established.

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Auburn, N. Y., January, 1910.

Art. XXXIII.—*Additions to the Pleistocene Flora of Alabama;* by Edward W. Berry.*

A brief contribution to the Pleistocene flora of Alabama was made by the writer in 1907† in which twelve species were described from the Pleistocene clays and peat outcropping along the Chattahoochee River near Abercrombe Landing in Russell County, a few miles below Columbus, Georgia. During the past field season the writer, in company with Dr. L. W. Stevenson, was engaged in studying the Mesozoic sections along the principal rivers of Alabama for the U. S. Geological Survey. In the course of this work Pleistocene plants were discovered at a number of scattered localities which it seems desirable to place on record at the present time. The localities will first be briefly described, after which the forms identified will be enumerated.

The present contribution extends the range of the ten species previously recorded from the Alabama Pleistocene and records the occurrence there of sixteen additional forms, bringing the total flora up to twenty-eight species. Among these the following existing species have not heretofore been found as fossils: *Pinus taeda* Linné, *Arundinaria macrosperma* Michx., *Hicoria villosa* (Sarg.) Ashe, *Populus deltoides* Marsh, *Phoradendron flavescens* (Pursh) Nutt., *Acer saccharinum* Linné, *Acer rubrum* Linné, and *Osmunda spectabilis* Willd. In addition the range of several species in the Pleistocene is seen to be quite different from their present range: for one thing the Fall-line which marks such an important line of demarcation in the distribution of our existing flora seems to have largely lost its significance at the time when the glaciers crowded our eastern Pleistocene flora southward and a large part of the coastal plain was submerged. However, any general conclusions may well be postponed until the completion of the writer's studies of the eastern Pleistocene floras.

Locality No. 1.—This locality is on the right bank of the Warrior River, about 356 miles above Mobile and about 200 yards above the mouth of Big Creek. The following section at this point is typical of much of the Pleistocene seen along the Alabama rivers, lacking only the gravel bed at the base of the section which is probably present at this point beneath water level:

Section.

1.	Brownish, massive, sandy clay	30 feet
2.	Brownish, laminated, iron-stained, sandy clay	6 "
3.	Dark, bluish gray, thickly-laminated, sandy clay with leaf impressions	8 "

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* Published by permission of the Director of the U. S. Geological Survey.

† Berry, Amer. Nat., vol. xli, pp. 639–697, pl. 1, 2, 1907.

The following species were identified from this outcrop: *Arundinaria macrosperma*, *Betula nigra*, *Quercus nigra*, *Phoradendron flavescens*, *Liriodendron tulipifera*, *Platanus occidentalis* and *Acer saccharinum*.

In the absence of topographic maps it is impossible to identify the various systems of Pleistocene terrace deposits which cross the state approximately parallel with the coast and which extend inland up the present rivers, passing insensibly from marine to estuarine, and finally to fluviatile conditions of deposition. The present outcrop is believed to form a part of the Northport terrace, which at Tuscaloosa is about 70 feet above low-water mark in the Warrior River and about 140 feet above sea level.

Locality No. 2.—This outcrop is on the right bank of the Warrior River about 342 miles above Mobile, and shows the following section:

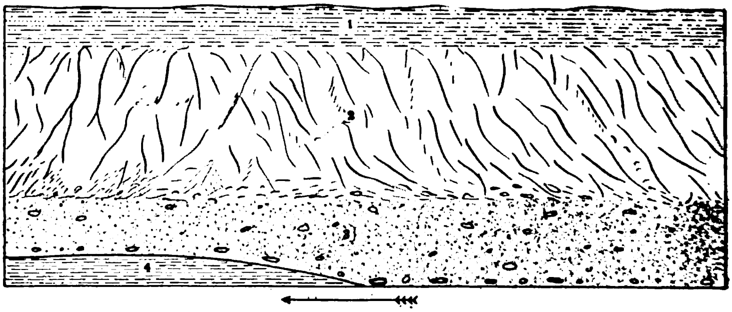
Section.

1. Yellow, massive, compact sandy clay, bedded and ferruginous below	20 feet
2. Light drab, yellowish and brownish sandy clay with pockets, thin seams and laminæ of fine micaceous sand and numerous thin iron crusts, becoming more sandy toward the base where a few pebbles of quartz and coal are found	7 "
3. Dark drab clay interbedded with yellowish sand and carrying much comminuted vegetable matter and leaf impressions toward the base	3 "
4. Concealed	8 "

The following species were identified from this outcrop: *Pinus echinata*, *Taxodium distichum*, and *Quercus phellos*.

Locality No. 3.—This outcrop is on the right bank of the Warrior River near Fosters Landing, about 328½ miles above Mobile. The following diagrammatical section (fig. 1) well illustrates the character of the materials at this point:

Fig. 1.



Diagrammatical Section of the Pleistocene at Locality No. 3.

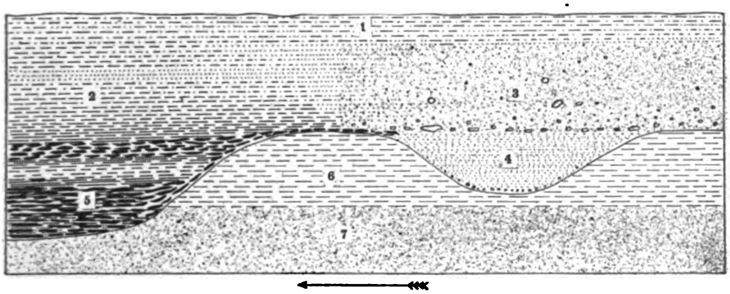
Section.

1.	Sandy clay	about	5 feet
2.	Similar materials concealed by landslips	"	15 "
3.	Sand with much gravel containing some pebbles of coal and rather angular bowlders of Paleozoic rocks up to 2 feet in diameter		7-10 "
4.	Massive, dark gray, finely micaceous, plastic clay with leaf impressions and overlain by a thin iron crust		0-3 "

The following species were identified from this outcrop: *Betula nigra*, *Populus deltoides*, *Liriodendron tulipifera*, *Platanus occidentalis*, and *Acer rubrum*.

Locality No. 4.—This outcrop is on the right bank of the Warrior River at Steeles Bluff, 311½ miles above Mobile, and is well illustrated by the following diagrammatical section (fig. 2).

FIG. 2.



Diagrammatical Section of the Cretaceous and Pleistocene at Locality No. 4.

Section.

Pleistocene.			
1.	Sandy clay	about	5 feet
2.	Light colored massive clay and sand with lignitic layers in both the clay and the sand, grading laterally, i. e. up the river, into the next (No. 3)	"	12 "
3.	Coarse yellowish sand with gravel and pebbles toward the base, lignitic at the base toward the lower end		
4.	Yellowish micaceous stratified sand with scattered small pebbles	"	10 "
5.	Sandy argillaceous peat with fruits, seeds, and leaf impressions		10–12 "
Upper Cretaceous (Tuscaloosa formation).			
6.	Blotched purplish, massive, somewhat sandy clay with iron crusts, much eroded		0–12 "
7.	Light gray, finely arkosic, slightly micaceous sand, argillaceous and compact in places		4–8 "

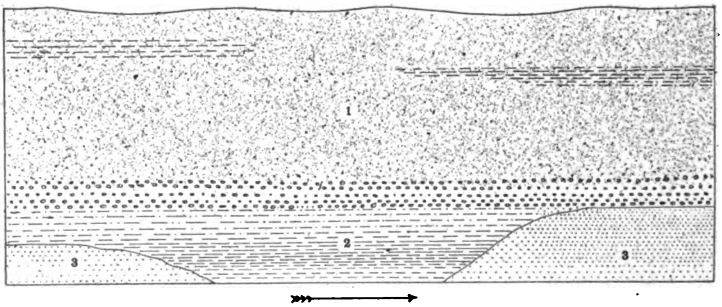
The following species were identified from this outcrop: *Osmunda spectabilis*, *Pinus taeda*, *Arundinaria macrosperma*, *Betula nigra*, *Fagus americana*, *Quercus nigra*, *Quercus prinus*, *Quercus phellos*, *Carpinus caroliniana*, *Ostrya virginiana*, *Ulmus alata*, *Hicoria villosa*, *Juglans nigra*, *Populus deltoides*, *Liquidambar styraciflua*, *Nyssa biflora*, *Vaccinium corymbosum*, *Xolisma ligustrina*.

Locality No. 5.—This locality is on the left bank of the Chattahoochee River and therefore in the state of Georgia. It is about one mile above the Abercrombe Landing exposure and is represented by three unimportant species found in pieces of Pleistocene clay along the river cove and not in place. The species are *Arundinaria macrosperma*, *Betula nigra*, and *Carpinus caroliniana*, all of which occur in the Alabama Pleistocene.

Locality No. 6.—This outcrop is on the right bank of the Chattahoochee River near Abercrombe Landing, about one mile below locality No. 5 and was described in the article previously mentioned.* The following species new to this locality were collected: *Pinus taeda*, *Populus deltoides*, *Phoradendron flavescens*, *Acer sacchaninum*.

Locality No. 7.—This outcrop shows the Pleistocene in a pocket of the Lower Cretaceous on the left bank of the Alabama River about one-half mile below Gun Island and about 12 miles above Montgomery. It is shown in the following diagrammatical section (fig. 3):

FIG. 3.



Diagrammatical Section of the Cretaceous and Pleistocene at Locality No. 7.

Section.

Pleistocene.

1. Light yellowish, somewhat argillaceous sand, with gravel base ....about 20 feet
2. Buff sandy clay with leaf impressions....... " 6 "

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* Berry, loc. cit., 1907.

Lower Cretaceous (Cape Fear Formation).

3. Compact, somewhat arkosic and micaceous sand, much eroded .... 0–5 feet

The following species were identified from this outcrop: *Fagus americana*, *Quercus nigra*, *Platanus occidentalis*, and *Vaccinium arboreum.*

There follows a briefly annotated enumeration of the species collected in systematic order, with citations of the fossil records of the various forms.

OSMUNDA SPECTABILIS WILLD.

The royal fern frequents swamps and openings and borders of wet woods. It ranges from Canada to Mexico and probably into South America, but is often confused with the old world *Osmunda regalis* Linné. In the existing Alabama flora it is common throughout the State. None of the existing species of *Osmunda*, which are six or eight in number, have heretofore been found fossil, although Hollick records* masses of rootlets attached to rhizomes in the swamp deposits of the Talbot formation in Maryland, which are almost certainly referable to *Osmunda.* The present record is based upon a single specimen showing a part of a pinnule and exhibiting the characteristic venation and marginal characters of this species found at locality No. 4.

TAXODIUM DISTICHUM (Linné) Rich.

Holmes. Journ. Elisha Mitchell Soc. for 1884–85, p. 92, 1885.
Berry, Torreya, vol. vi, p. 89, 1906. Jour. Geol., vol. xv, p. 339, 1907.
Hollick, Md. Geol. Surv., Pli. and Pleist., pp. 218, 237, pl. 68, 1906.

The cypress was probably one of the commonest forest trees of the Pleistocene from New Jersey southward, at least it is the one most frequently met with, having been recorded from New Jersey, Delaware, Maryland, Virginia, and North Carolina. The more northerly occurrences probably represent inter and post glacial warm periods. The recent collections show no trace of this species except at locality No. 2, where impressions of the detached leaves of this species are common in the clays

PINUS TAEDA Linné.

In the existing flora the Loblolly pine extends from Delaware and Maryland to Florida and Texas. In the northern part of its range it is confined to the coastal plain but farther south it spreads over the Piedmont Plateau and into the mountain region. In the Pleistocene it apparently extended farther north than at the present time since seeds which are believed to belong to this species have been collected by the writer from the Pleistocene of New Jersey.

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* Hollick, Md. Geol. Surv., Pli. and Pleist., p. 214, pl. 67, fig. 3, 1906.

The present record is based on cones and cone-scales from locality No. 4 and seeds from locality No. 6. The cones are frequent at the former locality but much water worn; some of the scales, however, preserve the characteristic markings of the species.

PINUS ECHINATA Mill.

Hollick, Md. Geol. Surv., Pli. and Pleist., p. 217, pl. 67, fig. 1, 1906.

This is a species found on sandy soils from New York to northern Florida and west to northeastern Texas, reaching its greatest development in the Mississippi Valley. Cones have been recorded in the Pleistocene as common in the Talbot formation of Maryland and the present record is based upon seeds which are common in the clay at locality No. 2.

ARUNDINARIA MACROSPERMA Michx.

In the recent flora this species forms those remarkable plant associations known as "canebrakes" in the bottom lands along the larger streams from southern Virginia to Florida and Louisiana and extending up the Mississippi Valley to Missouri and Kentucky. It has not previously been recorded in the fossil state but was evidently common in Alabama during Pleistocene time since characteristic fragments of the leaves have been collected from localities No. 1, 4, and 5.

JUGLANS NIGRA Linné.

Berry, Torreya, vol. ix, p. 98, fig. 6, 1909.

In the recent flora this species is found in rich soil from Canada to Minnesota and south to Florida and Texas. In Alabama according to Mohr it is found scattered in rich bottom lands from the Tennessee Valley to the Coast Pine belt, spreading southward along the banks of the larger rivers. As a fossil it was recently recorded by the writer from the Talbot formation in Maryland, the remains consisting of the characteristic nuts. The Alabama occurrence is based upon a single nut from locality No. 4.

HICORIA VILLOSA (Sargent) Ashe.

This species, differentiated from the common *Hicoria glabra* by Sargent, is an inhabitant of the Carolinian zone ranging from Delaware to Georgia and Alabama. In the latter state it is said to be one of the commonest hickories in the upland and mountainous parts of the state, extending southward to the Coast Pine belt. It has not been previously found fossil, the present record being based upon several husks and three nuts from locality No. 4. The latter are identical with the more globular nuts of the recent tree resembling somewhat in appearance the nuts of *Hicoria minima* but with much thicker shells.

POPULUS DELTOIDES Marsh.

In the existing flora this species ranges from Canada and New England westward to Colorado and southward to Florida and Texas. In Alabama and throughout the Coastal Plain it is most frequent in the bottoms and alluvial river swamps.

The genus extends back to the late Lower Cretaceous and a large number of extinct species have been described. The present species has not heretofore been found fossil, but both *Populus balsamifera* Linné and *grandidentata* Michx. are present in the Canadian inter-glacial deposits and Hollick has recorded three species from the Pleistocene of Maryland. From the European Pleistocene the following still existing species are known: *Populus alba* Linné, *canescens* Sm., *nigra* Linné, and *tremula* Linné.

The present record is based on the characteristic leaves which are abundant at locality No. 3 and less common at localities No. 4 and No. 6.

BETULA NIGRA Linné.

Knowlton, Amer. Geol., vol. xviiim, p. 371, 1896.
Berry, Journ. Geol., vol. xv, p. 341, 1907. Amer. Nat., vol. xli, p. 692, pl. 2, figs. 2–4, 1907. Ibid., vol. xliii, p. 435, 1909.

This species is common along streams and in bottoms with an existing range from Canada to Florida and Texas, and is common throughout Alabama. It was a common species in the Pleistocene, at least it was frequently preserved, and has been recorded by the writer from several localities in North Carolina and Virginia as well as from near Abercrombe Landing on the Chattahoochee River in Alabama. Knowlton has described it from the Pleistocene river terraces near Morgantown, West Virginia.

The present record is based on leaves from localities No. 1, 3, 4, and 5, they being especially abundant in the peat at locality No. 4.

FAGUS AMERICANA Sweet.

Hollick, Md. Geol. Surv., Pli. and Pleist., p. 226, 1906.
Berry, Torreya, vol. vi, p. 88, 1906. Journ. Geol., vol. xv, p. 341, 1907. Amer. Nat., vol. xli, p. 692, pl. 2, fig. 7, 1907. Ibid., vol. xliii, p. 435, 1909.
***Fagus ferruginea* Michx., Lesq., this Journal, vol. xxvii, p. 363, 1859. Geol. Tenn., p. 427, pl. 7 (K), fig. 11, 1869.**
***Fagus ferruginea* Ait., Knowlton, Amer. Geol., vol. xviii, p. 371, 1896. Mercer, Journ. Phila. Acad. (11), vol. ii, pp. 277, 281, fig. 8 (15), 1899.**

This common mesophile forest tree of the Alleghenian, Carolinian, and Louisianian zones which is common throughout Alabama is of frequent occurrence in the Pleistocene from Maryland southward and it has been recorded from a large number of localities, the buried swamp deposits usually furnishing remains of nuts or burrs, while the leaves are generally confined to the clays.

This species was recorded from near Abercrombe Landing in 1907 and additional occurrences are locality No. 4 (leaves, nuts, and burrs) and locality No. 7 (leaves).

QUERCUS PHELLOS Linné.

Berry, Journ. Geol., vol. xv, p. 342, 1907. Amer. Nat., vol. xli, p. 694, pl. 1, fig. 1, 1907.

This common mesophile tree of the Carolinian and Louisianian zones ranges from New York to Florida and Texas. It is common in northern Alabama, but becomes rare south of the central part of the state. It is a common fossil in the North Carolina Pleistocene and at Abercrombe Landing on the Chattahoochee River in Alabama.

The present occurrences are at locality No. 2 (leaves) and locality No. 4 (leaves, cupules and acorns).

QUERCUS NIGRA Linné.

Berry, Journ. Geol., vol. xv, p. 342, 1907. Amer. Nat., vol. xli, p. 693, pl. 1, figs. 3, 4, 1907.

In the existing flora this is a widespread species of the Carolinian and Louisianian zones extending northward to Delaware, Tennessee, and Missouri and common all over Alabama in low rich woods and swamps. As a fossil it has been recorded from the Pleistocene of North Carolina and eastern Alabama.

The present records are locality No. 1 (leaves), locality No. 4 (leaves and acorns, common) and locality No. 7 (leaves). One specimen from locality No. 4, while too imperfect for certainty, suggests its reference to *Quercus virginiana* Mill., a species previously recorded by the writer from Abercrombe Landing on the Chattahoochee River in Alabama.

QUERCUS PRINUS Linné.

Berry, Journ. Geol., vol. xv, p. 342, 1907. Amer. Nat., vol. xli, p. 693, pl. 1, fig. 2, 1907.

This is an upland tree of the Alleghanian and Carolinian zones, of rare occurrence in the southern Coastal Plain,* and since it is easy to confuse the leaves of this species with those of *Quercus michauxii*, a common tree of Coastal Plain bottoms, doubt has been expressed regarding the identifications cited above. However, it is believed that the fruit of *Quercus prinus* is sufficiently distinct for certainty, and when it is remembered that at some time during the Pleistocene practically the whole Coastal Plain was submerged by the sea and that there was a massing of species in the emerged portion of the southern Piedmont area, which served as a center of radiation for inter- and post-glacial dispersion,* the propriety of finding the species in the Pleistocene sediments is unquestionable.

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* This species has not been found in the Coastal Plain of Alabama, although Hilgard reported it years ago from Tippah County, Mississippi. In Georgia, according to R. M. Harper, it does not even approach the Fall-line, while in North Carolina it is confined to the Piedmont and mountains, according to Pichot and Ashe. Farther northward, however, it is found in the Coastal Plain from Long Island to Virginia, occurring in this province of New Jersey outside of the pine barrens and common on the upper eastern shore of Maryland and in Delaware.

The present record is based upon an acorn and leaf fragment from locality No. 4.

CARPINUS CAROLINIANA Walt.

Berry, Journ. Geol., vol. xv, p. 340, 1907. Amer. Nat., vol. xli, p. 692, pl. 1, figs. 8, 9, 1907.

This is a wide ranging species of low rich woods occurring from Canada to Florida and Texas. It is common in suitable situations over the greater part of Alabama and appears to have been frequent in the later Pleistocene of America, previous Pleistocene occurrences being along the Neuse River in the North Carolina Coastal Plain and from near Abercrombe Landing on the Chattahoochee River in Alabama.

The new records are localities No. 4 and No. 5, this species being especially common at the former of these.

OSTRYA VIRGINIANA (Mill.) Willd.

Hollick, Bull. Torrey Club, vol. xix, p. 332, 1892.
Penhallow, Amer. Nat., vol. xli, p. 447, 1907.

In the recent flora this species ranges from Canada to Florida and Texas, ordinarily in dry soil and on hillsides. It is said by Mohr to occur principally on calcareous soils in Alabama, where it ranges from the Tennessee Valley to the upper division of the coast pine belt, its southern limit corresponding roughly to the northern limit of the Cuban pine. In the fossil state it is recorded by Hollick from the late Miocene or Pliocene of Bridgeton, New Jersey, and by Penhallow from the interglacial deposits of the Don valley in Canada. Material indistinguishable from the modern species has been described by Nathorst from the post-Miocene of Japan under the varietal name *fossilis*. Finally the material from Wytheville, Virginia, said to be of Pleistocene age, which was identified by Lesquereux† as *Ostrya Walkeri* Heer, an early

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* See the various papers by C. C. Adams on this subject.
† Lesq., Proc. U. S. Natl. Mus., vol. x, p. 38, 1887.

Tertiary arctic species, is probably identical or closely allied with the present species.

The present occurrence consists of leaves which are infrequent at locality No. 4.

ULMUS ALATA Michx.

Lesq., this Journal, vol. xxvii, p. 365, 1859.
Berry, Journ. Geol., vol. xv, p. 343, 1907. Amer. Nat., vol. xli, p. 694, pl. 1, figs. 6, 7, 1907.

This species is a common element in the recent flora of Alabama in low woods particularly along stream banks. It ranges northward to Virginia, Illinois and Kansas and southward to Florida and Texas. As a fossil it was recorded from the Pleistocene near Columbus, Kentucky, by Lesquereux, and from the Neuse River in North Carolina and Abercrombe Landing on the Chattahoochee River in Alabama by the writer (loc. cit.). Two species of Ulmus occur in the Pleistocene of Maryland, *Ulmus racemosa* is recorded from the Pleistocene near Morgantown, West Virginia, and both the latter and *Ulmus americana* occur in the interglacial beds of the Don valley in Canada.

The present record is based upon infrequent leaves from locality No. 4.

PHORADENDRON FLAVESCENS (Pursh) Nutt.

A species, in the modern flora, of the Carolinian and Louisianian zones ranging northward as far as New Jersey and common throughout Alabama. It has not previously been recorded as a fossil, although certain European Upper Pliocene remains have been described as *Viscophyllum*. However, it is not at all certain that these are not related to the genus *Pistia* rather than to *Viscum*.

The present record is based on the characteristic leaves of the modern species found at localities No. 1 (common) and No. 6 (1 specimen).

LIRIODENDRON TULIPIFERA Linné.

Berry, Amer. Nat., vol. xli, p. 695, 1907. Torreya, vol. ix, p. 71, fig. 1, 1909.

This common mesophile forest type of the Alleghanian, Carolinian, and Louisianian zones finds its present southern limit in Alabama at about latitude 31°. Previous fossil records are based on fruits from Abercrombe Landing on the Chattahoochee River in Alabama and upon abundant leaves from the Wicomico formation near Weldon, North Carolina.

The present record is based upon leaf fragments from locality No. 1 and upon a leaf and a carpel from locality No. 3.

PLATANUS OCCIDENTALIS Linné.

Knowlton, Amer. Geol., vol. xviii, p. 371, 1896.
Penhallow, Trans. Roy., Soc. Can. (II), vol. ii, sec. 4, pp. 68, 72, 1897. Amer. Nat., vol. xli, p. 448, 1907.
Mercer, Journ. Phila. Acad. (II), vol. ii, p. 277, 1899.
Berry, Journ. Geol., vol. xv, p. 344, 1907. Amer. Nat., vol. xli, p. 695, pl. 2, fig. 5, 1907.
Platanus aceroides Göpp., Hollick, Md. Geol. Surv., Pli. and Pleist., p. 231, pls. 73, 74, 1906.

This modern inhabitant of low woods and banks from Canada to Florida and Texas is frequent in the bottom lands of central Alabama but not common elsewhere in the state. As a fossil it is of frequent occurrence in Pleistocene deposits from those of the Don Valley in Canada to Alabama.

The present record is based upon characteristic leaves which occur in considerable abundance at localities No. 1, No. 3, and No. 7.

LIQUIDAMBAR STYRACIFLUA Linné.

Hollick, Bull. Torrey Club, vol. xix, p. 331, 1892.
Knowlton, Amer. Geol., vol. xviii. p. 371, 1896.
Berry, Journ. Geol., vol. xv, p. 343, 1907.

This species ranges from New England to Florida and westward to Texas and Mexico in the recent flora and is found throughout Alabama, more especially in the rich bottoms and swamp borders of the Coastal Plain. It has previously been recorded from the Pleistocene of North Carolina and West Virginia. The present record is based upon leaf fragments and upon two somewhat macerated and flattened but characteristic fruits from locality No. 4.

ACER RUBRUM Linné.

A species of swamps and low ground ranging from Canada to Florida and Texas in the existing flora and common throughout Alabama, not previously known as a fossil. The present record is based upon leaf fragments from locality No. 3.

ACER SACCHARINUM Linné.

This species in the existing flora ranges from Canada to Florida and westward to the Great Plains. It extends from northern Alabama southward along the larger streams. It has not been previously recorded from the Pleistocene, the form described by Penhallow under this name from the Canadian Pleistocene being referable to *Acer saccharum* Marsh.

The present record is based on characteristic samaras from locality No. 1 and No. 6.

NYSSA BIFLORA Walt.

Hollick, Md. Geol. Surv., Pli. and Pleist., p. 235, pl. 69, fig. 5, 1906. Berry, Torreya, vol. vi, p. 90, 1906. Journ. Geol., vol. xv, p. 345, 1907.

This species in the Recent appears to be confined to the Coastal Plain, ranging from Virginia to eastern Texas. As a fossil it has been recorded from the Pleistocene of Maryland, Virginia, and North Carolina. The present record is based upon leaves from locality No. 4.

VACCINIUM ARBOREUM Marsh.

Berry, Torreya, vol. ix, p. 73, 1909.

This species, which ranges from Virginia to Indian Territory and southward to Florida and Texas in the Recent, has previously been recorded from the Pleistocene of North Carolina. The present material comes from locality No. 7. The genus is wide ranging and a number of Pleistocene occurrences are known both in this country and abroad. Thus in addition to the next species, *Vaccinium spatulata* Berry occurs in the Pleistocene of North Carolina and *Vaccinium uliginosum* Linné at Scarboro Heights, Ontario, *Vaccinium maderense* Link is known from the Pleistocene of Madeira and *Vaccinium myrtillus* Linné and *Vaccinium vitis-idœa* Linné occur in the interglacial peats of the southern uplands in Scotland.

VACCINIUM CORYMBOSUM Linné.

Hollick, Md. Geol. Surv., Pli. and Pleist., p. 236, pl. 69, figs. 7–9, 1906. Berry, Journ. Geol., vol. xv, p. 346, 1907.

This species ranges in the modern flora from Canada to Louisiana and in Alabama is said to be confined to the mountain region. As a fossil it is recorded from Maryland and North Carolina. The present record is based upon leaves from locality No. 4.

XOLISMA LIGUSTRINA (Linné) Britton.

Hollick, Md. Geol. Surv., Pli. and Pleist., p. 236, pl. 69, fig. 6, 1906. Berry, Journ. Geol., vol. xv, p. 346, 1907. Amer. Nat., vol. xli, p. 696, pl. 2, fig. 6, 1907.

This species has been previously recorded in the Pleistocene of Alabama as well as from Maryland and North Carolina. The present record is based on leaves from locality No. 4.

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ART. XXXIV.—*The Application of Potassium Ferricyanide in Alkaline Solution to the Estimation of Arsenic, Antimony, and Tin;* by HOWARD E. PALMER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccx.]

In 1892, Quincke* published a method for estimating arsenic and antimony gasometrically, consisting essentially in oxidizing the arsenic or the antimony by a known excess of potassium ferricyanide in the presence of alkali, and determining the excess by measuring in a gasometer the oxygen evolved by the action of hydrogen peroxide on it according to the following equation:

$$2K_3FeC_6N_6 + H_2O_2 + 2KOH = 2K_4FeC_6N_6 + 2H_2O + O_2.$$

In previous papers from this laboratory, methods for the estimation of cerium in the presence of the other rare earths,† and for the estimation of thallium,‡ have been described, based on oxidation by potassium ferricyanide in alkaline solution and titration with permanganate of the ferrocyanide formed.

The work to be described is the result of an attempt to apply this reaction to the estimation of arsenic, antimony, and tin, which are oxidized according to the following equations:

$$As_2O_3 + 4K_3FeC_6N_6 + 4KOH = As_2O_5 + 4K_4FeC_6N_6 + 2H_2O.$$
$$Sb_2O_3 + 4K_3FeC_6N_6 + 4KOH = Sb_2O_5 + 4K_4FeC_6N_6 + 2H_2O.$$
$$SnO + 2K_3FeC_6N_6 + 2KOH = SnO_2 + 2K_4FeC_6N_6 + H_2O.$$

The ferrocyanide formed is then oxidized by permanganate according to the equation

$$10K_4FeC_6N_6 + 2KMnO_4 + 8H_2SO_4 = 10K_3FeC_6N_6 + 6K_2SO_4 + 2MnSO_4 + 8H_2O.$$

Estimation of Arsenic.

The essential procedure was to oxidize the arsenic by potassium ferricyanide in alkaline solution, and after making ammoniacal by the addition of ammonium sulphate, to precipitate the arsenic by magnesia mixture, filter off the ammonium magnesium arseniate, and titrate the filtrate with permanganate, after acidification with sulphuric acid.

For the work a solution of arsenious acid was prepared in the usual way by dissolving pure sublimed arsenious oxide in potassium hydroxide, neutralizing with sulphuric acid and adding sodium bicarbonate. The magnesia mixture used was made up by dissolving 55 grams of the crystallized magnesium chloride and 29 grams of purified ammonium chloride in a liter of water, with the addition of about 5 cubic centimeters of concentrated ammonium hydroxide. The potassium ferricyanide used was purified by recrystallization, but even then, as in the previous work, it was necessary to apply a correction to the determinations for the number of cubic centimeters of permanganate required to give the pink coloration to the ferricyanide alone, generally amounting to about one-tenth of one cubic centimeter. A solution of potassium ferricyanide of convenient strength for use in the determination of all three elements contained 20 grams to 100 cubic centimeters.

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* Zeitschr. f. Anal. Chem., xxxi, 1.

† This Journal, xxvi, 83.

‡ This Journal, xxvii, 379.

In the preliminary experiments, recorded in Table I, low results were obtained, apparently due to the incomplete oxidation of the arsenic by the amounts of ferricyanide and potassium hydroxide used. If at least ten times the theoretical amount of ferricyanide, with a rather dilute solution of potassium hydroxide, is used, as in experiments (1) to (12) of Table II, the oxidation is complete; or, if a more concentrated solution of potassium hydroxide is used, as in experiments (13) and (14) of Table II, less ferricyanide is necessary. In any case, it is advantageous that the total volume of the solution be rather small, preferably less than 100 cubic centimeters, since, as shown by experiments (4), (5), and (6) of Table I, if the volume is greater than that, low results are obtained.

Table I.

	As_2O_3 taken grm.	$K_3FeC_6N_6$ grm.	KOH grm.	Vol. of sol. cm^3.	As_2O_3 found grm.	Error grm.
(1)	0·0997	2	1·25	100	0·0966	—0.0031
(2)	0·0997	4	1·25	75	0·0987	—0·0010
(3)	0·1496	8	1·25	100	0·1486	—0·0010
(4)	0·0997	8	1·25	150	0·0982	—0·0015
(5)	0·0997	4	2·5	175	0·0978	—0·0019
(6)	0·1001	4	4·	150	0·0984	—0·0017

The procedure to be recommended, therefore, is as follows: To the solution containing the arsenic in the arsenious condition is added an amount of potassium ferricyanide equal to at least five times the amount theoretically required to oxidize the arsenic to the higher condition of oxidation, and about 25 cubic centimeters of a 20 per cent solution of potassium hydroxide, keeping the volume of the solution less than 100 cubic centimeters. After standing a few minutes, the solution is made ammoniacal by dissolving in it about 10 grams of ammonium sulphate, which acts on the potassium hydroxide, set-

TABLE II.

	As_2O_3 taken grm.	$K_3FeC_6N_6$ grm.	KOH grm.	Vol. of sol. cm$_3$.	As_2O_3 found grm.	Error grm.
(1)	0·0499	8	1·25	100	0·0502	+0·0003
(2)	0·0499	4	1·25	75	0·0499	±0·0000
(3)	0·0499	3	1·25	75	0·0501	+0·0002
(4)	0·0501	4	1·25	75	0·0500	−0·0001
(5)	0·0997	8	1·25	100	0·0999	+0·0002
(6)	0·0997	6	1·25	90	0·0993	−0·0004
(7)	0·0997	6	1·25	90	0·0993	−0·0004
(8)	0·1001	8	1·25	100	0·0998	−0·0003
(9)	0·1496	9	1·25	110	0·1492	−0·0004
(10)	0·1496	10	1·25	110	0·1496	±0·0000
(11)	0·1502	10	1·25	110	0·1502	±0·0000
(12)	0·1994	12	1·25	125	0·1994	±0·0000
(13)	0·1001	4	4·	75	0·0998	−0·0003
(14)	0·1001	3	4·	75	0·0998	−0·0003

ting free ammonia, and about 100 cubic centimeters of the magnesia mixture are added. After settling, the ammonium magnesium arseniate is filtered off on asbestos, and washed with faintly ammoniacal water. The filtrate is strongly acidified with dilute sulphuric acid, and titrated with permanganate.

As Grützner* has shown, during the titration of large amounts of ferrocyanide by permanganate, a precipitate of $K_2MnFeC_6N_6$ often forms by the action of the manganese sulphate, which is formed by reduction of the permanganate, on the unchanged ferrocyanide. This precipitate slowly clears up as more permanganate is added, clearing up entirely as the end point is reached, but it tends to cause high results, on account of the difficulty in noting the end point exactly. It was found, in connection with the present work, that by titrating in the presence of a large amount of sulphuric acid, the formation of this precipitate is prevented. The titration may safely be made in the cold in the presence of ten per cent of sulphuric acid, and this amount will generally be sufficient to prevent the formation of the precipitate.

Determination of Antimony.

A solution of antimony trichloride was made up by dissolving pure antimony trioxide in hydrochloric acid, and diluting to a definite volume with the addition of sufficient hydrochloric acid to prevent the formation of the basic salt; the standard of this solution was determined by titrating with standard iodine.

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* Chem. Centralblatt, 1902, I, 500.

The procedure was, in general, the same as in the determination of arsenic, except that it was found unnecessary to remove the antimony before titrating with permanganate. At least five times as much potassium ferricyanide as theoretically necessary was added in solution, and about 25 cubic centimeters of a 20 per cent solution of potassium hydroxide. After standing a few minutes, the solution was strongly acidified with dilute sulphuric acid and titrated with permanganate. The results are given in Table III.

TABLE III.

	Sb_2O_3 taken grm.	$K_3FeC_6N_6$ grm.	KOH grm.	Vol. of sol. cm³.	Sb_2O_3 found grm.	Error grm.
(1)	0·0986	8	4	100	0·0989	+0·0003
(2)	0·0986	4	4	75	0·0984	−0·0002
(3)	0·0986	2	4	75	0·0984	−0·0002
(4)	0·0986	4	4	150	0·0984	−0·0002
(5)	0·0986	4	4	75	0·0984	−0·0002
(6)	0·0493	4	4	75	0·0495	+0·0002
(7)	0·0493	4	4	75	0·0497	+0·0004
(8)	0·0493	4	4	75	0·0495	+0·0002
(9)	0·1479	4	4	75	0·1482	+0·0003
(10)	0·1479	4	4	75	0·1477	−0·0002
(11)	0·1479	4	4	75	0·1476	−0·0003
(12)	0·1971	8	8	125	0·1972	+0·0001

Determination of Tin

Definite portions of metallic tin were accurately weighed out and dissolved in concentrated hydrochloric acid; it was found necessary to perform this operation in the cold, and to keep an atmosphere of hydrogen over the liquid during solution of the tin, as under other conditions results lower than the theoretical were obtained, indicating that the stannous salt had been partially oxidized by the air or by dissolved oxygen. When the tin was completely dissolved, a solution containing at least five times as much potassium ferricyanide as theoretically necessary was added, and enough of a solution of potassium hydroxide to completely dissolve the precipitated stannic acid, the two solutions of ferricyanide and potassium hydroxide having been previously mixed. The stannic salt was removed by the addition of about ten grams of ammonium sulphate, and warming to 50° or 60°, under which conditions the tin was completely precipitated. After it had settled, the precipitate was filtered off on asbestos, under gentle pressure, and washed with a 10 per cent solution of ammonium sulphate. The filtrate was strongly acidified with sulphuric acid, and titrated with permanganate in the usual manner. The results of the determinations are recorded in Table IV.

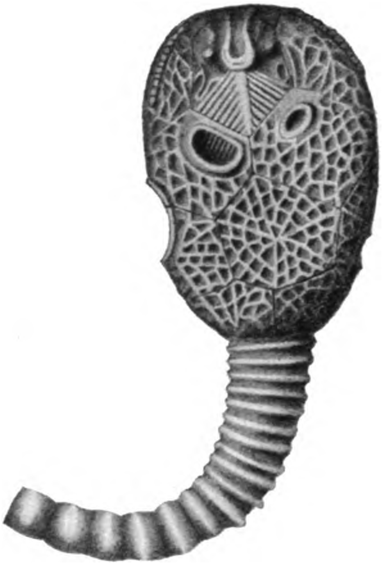
TABLE IV.

	Sn taken	$K_3FeC_6N_6$	KOH	Vol. of sol.	Sn found	Error
	grm.	grm.	grm.	cm³	grm.	grm.
(1)	0·1032	2·5	6	65	0·1033	+0·0001
(2)	0·1022	2·5	6	65	0·1016	−0·0006
(3)	0·1029	3·	7	60	0·1030	+0·0001
(4)	0·1009	5·	6	85	0·1011	+0·0002
(5)	0·1005	5·	5	60	0·1010	+0·0005
(6)	0·1011	10·	5	85	0·1015	+0·0004
(7)	0·0995	10·	5	85	0·1004	+0·0009
(8)	0·2020	4·	6	80	0·2019	−0·0001
(9)	0·2003	5·	6	90	0·1998	−0·0005
(10)	0·2021	10·	5	85	0·2027	+0·0006

ART. XXXV.—*A New Cystid from the Clinton Formation of Ontario—Lepadocystis clintonensis*; by WILLIAM ARTHUR PARKS.

IN 1873, F. B. Meek described a peculiar Cystid from the upper part of the Cincinnati formation at Richmond, Ind., under the name of *Lepocrinites moorei.*[*] This form, according to Meek, differs from all other examples of *Lepocrinites* by the possession of four instead of three pectinirhombs and five instead of four arms. P. H. Carpenter[†] regards these peculiarities as of generic value, and proposes to establish the genus *Lepadocystis* for the reception of Meek's species. Jaekel, in 1899, suggests *Meekocystis* as the generic name, but Bather gives precedence to Carpenter's name and recognizes the genus as a distinct member of the sub-family *Callocystinæ* of the *Glyptocystidæ.*[‡]

FIG. 1.



Lepadocystis clintonensis, sp. nov.

FIG 1. Viewed from the right postero-lateral aspect. × 3

So far as I am aware, no other example of the genus has hitherto been described, so that its discovery at a higher horizon, the Clinton, is worthy of note. This formation is possessed of a very meagre Echinoderm fauna, the exposures in Ontario having yielded only a few fragmentary Crinoids. The present example lay for a long time in our collection as an unidentifiable specimen. Recently, however, an attempt to clean it was made with unexpectedly satisfactory results. By sawing the specimen out and treating it with caustic potash the organism was entirely freed from the matrix, so that it now shows the chief anatomical peculiarities in an excellent manner.

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[*] Geol. Sur. Ohio, Paleontology, vol. i, pp. 39–41, pl. iii, figs. 4a and 4b.

[†] Jour. Linn. Soc. Zool., vol. xxiv, p. 10.

[‡] A Treatise on Zoölogy, E. Ray Lancaster, vol. iii, the Echinoderma, p. 61.

Adopting the method of numbering the plates proposed by Forbes,* we have, in the lower circlet, four plates, of which 1 and 2 are regularly pentagonal. Plate 4 is irregularly pentagonal, and 3 is hexagonal with its upper edge curved inwards. Of the second circlet, plates 5 and 6 are irregularly hexagonal: 7 is also hexagonal, but it has an heptagonal appearance owing to the encroachment of the anal orifice on its upper, right-hand angle. Plate 8 is smaller than 7 and is likewise deeply cut by the anus on its upper left-hand corner; its lower side is curved to fit into plate 3. Plate 9 is irregularly hexagonal. Of the third circlet, plates 10, 11 and 12 are hexagonal, but 12 is larger and more irregular than the other two. Plate 13 is narrower and reaches farther up the cup than any other plate of the ring: it is five-sided or six-sided if the deep anal excavation on its lower right-hand angle is included. Plate 14 is large and hexagonal, with the anal notch in the lower left-hand corner. The five plates of the fourth circlet (16, 17, 18, 19, 15) are pentagonal with the upper margin deeply notched for the ambulacral furrows. The plates of the fifth circlet (21, 22, 23, 24, 20) are small and almost indistinguishable in the specimen.

FIG. 2.

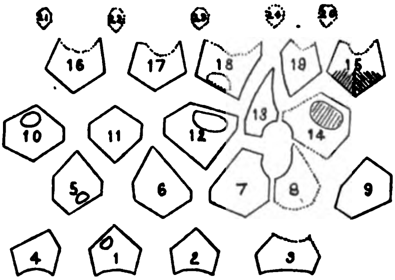

FIG. 2. Dissection of cup.

All the plates of the cup are ornamented with polygonal ridges, separated by shallow depressions. On the first two circlets of plates these ridges are radially arranged, but on the upper plates this regularity is lacking.

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* Memoirs of the Geol. Survey of Great Britain, vol. ii, pt. ii, p. 488.

Pectinirhombs appear across the sutures between plates 1 and 5, 12 and 18, 14 and 15, and 10 and 18. Pectinirhomb 1–5 presents two small, oval discrete halves without apparent stereom folds. Pectinirhomb 12–18 is larger: the half on plate 12 shows indistinct stereom folds, but that on 18 is almost destroyed. Pectinirhomb 14–15 has a large oval half on 14, presenting eight folds of stereom and lip-like margins. The half on 15 is triangular in shape, with stereom folds reaching to the suture and not confined by a lip. Pectinirhomb 10–15 has a small, oval, lipped, discrete half on 10. The portion on 15 is exactly the same as the other half-rhomb belonging to that plate.

The anus is large and is situated at the angle between plates 7, 8, 13 and 14. These plates are deeply excavated by the anal margin, which is raised into an oval or circular ridge.

Except for distinct evidence of their original presence on the median line of each plate of the fourth circlet, the ambulacral furrows are not perceptible.

The column is round and tapers distally. The first ten segments show a sharp median crest and occupy a space of about 7^{mm}. They show a gradually increasing thickness distally. Beyond the tenth segment, the median crest is less defined, the segments gradually becoming barrel-shaped. The 17th segment is 2^{mm} long and of about the same width.

The present example differs from Meek's species in its larger size, being 15^{mm} high by 10^{mm} wide, while the genotype is $11{\cdot}5^{mm}$ by 9^{mm}. The column, at its proximal end, is 4^{mm} thick as compared with $3{\cdot}5^{mm}$ in Meek's species. The sculpturing of the plates is different, as *L. moorei* shows only "thread-like, radiating costæ, one of which, passing from the middle to each side of each plate, is usually slightly larger than the others between." The shape and arrangement of the plates of the cup are strikingly alike in the two species.

Horizon—Clinton.
Locality—Forks of the Credit River, Ontario.
Collector—Mr. Joseph Townsend.
Specimen number—University of Toronto Museum, No. 372 Cl.

Art. XXXVI.—*A New Petrographic Microscope;* by Fred. Eugene Wright.

Experience has shown that the so-called universal instruments are as a rule unsatisfactory, and often do not accomplish in a thoroughly competent manner any one of the several purposes for which they are intended. To fulfill a given set of conditions adequately, it is usually necessary that a special instrument be designed for the purpose. Thus, a small calibre rifle may be admirably suited for small game, but for larger game it is totally inadequate and might even be of more harm than service in an emergency; and vice versa, a large calibre rifle is of little value in hunting small game.

The same principle of adaptability applies equally to microscopes and scientific apparatus in general. The ordinary microscope, which is designed to aid in the examination of thin sections of rocks and minerals, is satisfactory and convenient for such purposes, but is less so for use in the investigation of artificial preparations which are usually very fine-grained, the diameter of the individual grains averaging often not more than $\cdot 01^{mm}$. To determine satisfactorily and with fair accuracy the optical constants of substances in such minute grains, special methods of attack are required, and these in turn postulate certain new conditions to be fulfilled by the petrographic microscope. It was with this end in view, to construct a microscope better adapted than the microscopes now available for the examination and determination of fine-grained artificial silicate preparations, that the present microscope was designed and constructed in the workshop of the Geophysical Laboratory. Several of its features appear to be of general application, and a brief description of its essential parts is therefore justified.

In the construction of the present instrument (fig. 1), a Zeiss microscope No. 1 C for photomicrography served as base, and on it extensive changes were introduced so that the resulting microscope resembles the original only slightly. This particular model was chosen chiefly because of its wide upper barrel, which was well adapted for the introduction of diaphragms and the movable Bertrand lens. The changes which have been introduced are essentially as follows.*

(1) The nicols are revolvable simultaneously about the optic axis of the microscope. They are connected rigidly by the bar T of fig. 1, and their angle of revolution can be read off directly by the vernier on the stage. This method obviates the errors introduced by the usual system of gear-wheels with accompanying lost motion in the moving parts. The details of

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* A still further change, made recently and not shown in fig. 1, is the introduction of a block just below the upper tube support. The distance between the stage and the upper tube is thereby increased and the use of the universal stage facilitated.

FIG. 1.

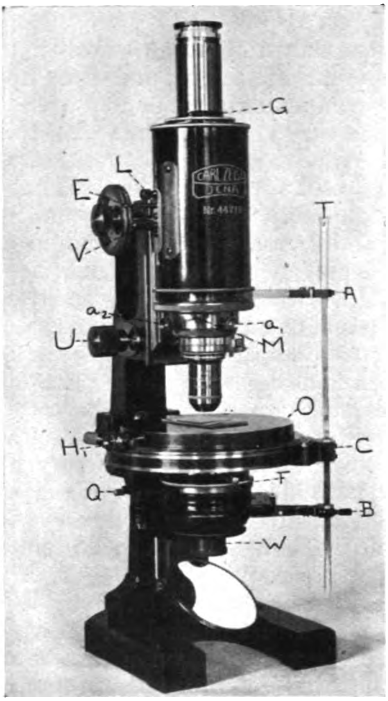

FIG. 1. New petrographic miscroscope. T, rigid bar connecting two nicols and effecting simultaneous revolution of the same; A, arm connecting upper nicol carriage with T; C, part supporting bar T and revolving about stage: B, arm from lower nicol carriage connecting with bar T; by means of the screw and cross plate at B, this arm can be instantly released from T and the lower nicol either revolved by itself or, after a release by a snap spring not shown in the figure, thrown out of the field altogether. The total angle of simultaneous revolution of both nicols by this device is 190°. O, new mechanical stage, simple in design and construction and fairly dust-proof. H_1, stage screw with divisions on head reading to ·01^{mm} motion of stage plate. Q, sensitive-tint plate inserted above lower nicol, W, and revolvable about microscope axis by means of containing carriage, F. M, combination wedge above objective; a_1 a_2, fine adjustment screws above objective; U, screw of fine adjustment device of upper microscope tube; V, iris diaphragm below Bertrand lens, diaphragm opened and closed by turning head V, which is connected with iris diaphragm by pin and ratchet movement; E, pin for insertion of Bertrand lens which moves in an accurately fitting carriage, supporting iris diaphragm V, Bertrand lens E and auxiliary lens L, which swings on an arm indicated in fig. 1a and is of such focal length that together with ocular, it forms a small microscope used in focusing the image from the objective in the plane of the iris diaphragm, V. The supporting carriage of V, E, and L, can be moved up and down in the microscope tube and the amount of movement read off on the adjacent scale, thus obtaining different magnifications (6·5 to 15·2 diameters) of the interference figure. G, upper iris diaphragm directly beneath ocular.

Figs. 1a, 2, 3.

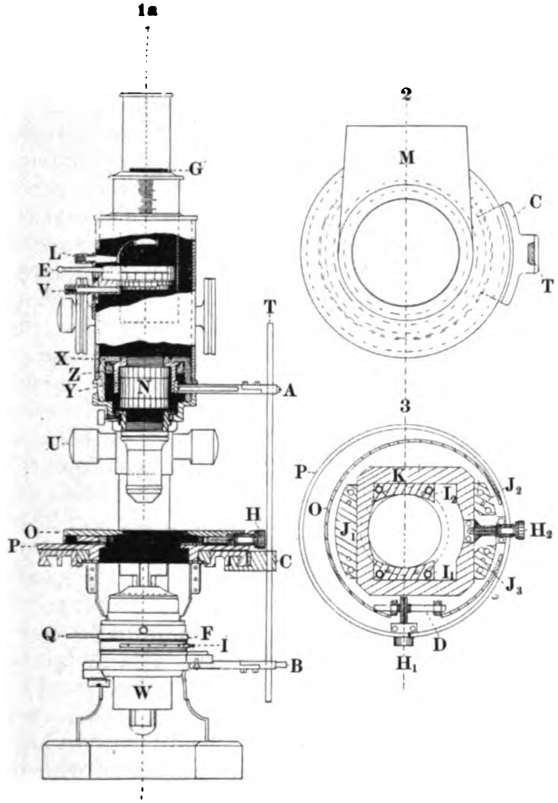

Fig. 1a. Section through microscope of fig. 1, showing working parts. The letters T, A, B, C, H, W, Q, F, O, U, V, E, L, and G, refer to the same parts as in fig. 1. I = lower iris diaphragm; N, upper nicol; X, Y, Z, brass parts effecting revolution of upper nicol; P, revolving stage supporting movable plate, O.

Fig. 2. Section showing stage P and microscope plate supporting stage and other revolving parts and support for revolving nicol device, C; T, cross section of bar connecting two nicols; this bar slides accurately in the arms A and B of fig. 1a.

Fig. 3. Cross section through mechanical plate 1 of stage. I_1, I_2, brass plates screwed to revolving stage P and with wedge-shape sides in which rectangular plate K can move in an east-west direction, the movement being effected by the screw H_2. J_1, J_2 and J_3, three plates attached to under side of stage plate, O, and forming grooves for plate K, permitting stage plate O to move only in north-south direction, the movement being accomplished by screw, H_1, which in turn fits in a sliding block attached to the upper plate O, and traveling in the pin, D.

construction are shown in fig. 1a. By means of the screw and cross bar at B the connecting rod T can be instantly released and the lower nicol withdrawn or revolved by itself independently of the upper nicol. The total angle through which both nicols can be revolved by this device is 190°.*

(2) A mechanical stage of new design† (fig. 3). This stage is practically dust-proof and mechanically simple in construction. In fig. 3. the vertical edge or rim of the cap, O, of the stage plate is indicated by the shaded broken circle, the upper surface of this plate being considered removed and the working parts as seen from above thus exposed to view. The small plates I_1 and I_2 are attached to the lower stage and are so constructed that wedge-shaped edges allow the rectangular plate K to move only in an east-west direction. This movement is effected by means of the screw H_2. The plates J_1, J_2 and J_3 of fig. 3, on the other hand, are attached to the upper movable plate O, and their wedge-shaped edges are so adjusted that they allow the upper plate to move only in a north-south direction with reference to the rectangular piece K. The screw H, which terminates in a block attached to the upper plate and running in a sliding pin D, accomplishes these north-south movements. The heads of both screws H_1 and H_2 have divisions reading to $\cdot 01^{mm}$ movement. Springs not indicated in the figure have been introduced and oppose the forward motion of the screws H_1 and H_2 and thus obviate errors due to lost motion in the screws. The total movement of the stage plate in any direction is 24^{mm}. Mechanically, it is of simple construction and consists of few parts.

(3) The metal part containing iris diaphragm and polarizer can be withdrawn from the optic axis of the microscope by means of a release spring not shown in fig. 1. This part is also revolvable by itself about the axis. This arrangement was adopted in preference to the usual method of inserting and withdrawing the upper nicol because of the disturbing effect which the introduction of the upper nicol causes, both on the focus and position of the field. With the present disposition, the upper nicol ‡ remains permanently in the upper tube and the optical system, objective, nicol, and ocular, is not disturbed in passing from ordinary to polarized light. In certain microscopes the effect of the upper nicol on change of focus is compensated by means of a small lens of weak magnifying power, but even after the introduction of this device some shifting of the field may still be experienced on inserting the upper nicol.

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* Fuess & Company have recently constructed, at the writer's suggestion, a simplified model of microscope on this principle of a rigid bar connection between the two nicols, so that the two can be revolved simultaneously. (Price 300 mks.)

† This stage was designed by Mr. Chamberlin of this laboratory, and constructed by Mr. Semple.

‡ For certain positions of the reflector and on certain days the light from the reflector is polarized to such an extent that faint polarization colors are observed on minerals in the thin section even after the polarizer has been withdrawn. For this reason it would be an improvement if the upper nicol also could be withdrawn readily, whenever desirable. This is the case on the model constructed by Fuess & Co., noted above.

(4) An Abbe condenser is used, and with it a large nicol prism, or an Ahrens prism, 15^{mm} edge, after the manner of the Fuess microscope No. 1a. With this arrangement the entire condenser lens system remains in position and its upper lens need not be removed when low-power objectives are used. This does away with the devices which have been employed for throwing the upper part of the condenser combination out of the axis of the optic system and which complicate the construction considerably.

(5) The selenite, or quartz, plate of sensitive tint is inserted in a metal case at Q (fig. 1), just below the condenser. It is revolvable in the carriage F about the optic axis of the microscope, an arrangement which often facilitates the determination of the ellipsoidal axis of a particular section because the abrupt rise or fall of interference colors on insertion and rapid revolution of the plate appears more clearly than if the slower moving stage itself were revolved. At M a combination wedge is introduced as in ordinary microscopes.

(6) The Bertrand lens E, fig. 1, is mounted on a sliding arrangement which, in connection with the sliding ocular tube, permits of different magnifications of the interference figure, an arrangement already adopted on several well-known microscopes. In the present microscope the focal length of the Bertrand lens (55^{mm}) has been so calculated that the initial magnification of the interference figures can be varied from ·81 diameters to 1·90 diameters. The ocular itself magnifies this image in turn eight-fold, so that the resulting magnifications range from about 6·5 to 15·2 diameters. The fact that the upper nicol intervenes between the objective and Bertrand lens limits very materially the range of magnifications possible by the Bertrand lens. An iris diaphragm is introduced directly below the Bertrand lens and slides up and down simultaneously with it. This diaphragm is opened and closed by means of the pin, V, fig. 1a, which is connected with the diaphragm itself by means of pin and ratchet movement.

(7) A second iris diaphragm is introduced at G, fig. 1, directly below the ocular, and is used in connection with the observation of interference figures by the Lasaulx method without the Bertrand lens. To be of service in this connection, the iris diaphragm should be located precisely in the image plane from the objective, as was emphazised especially by Czapski in 1891,* for in that plane alone can light be excluded from adjacent minerals in the thin section. To realize satisfactorily this condition, the writer has heretofore used the cap stop indicated by fig. 4, with two sets of slides, S_1 and S_2, at right

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* Neues Jahrbuch, Beilage Band vii, 506, 1891.

angles to each other. This cap fits the microscope tube and is inserted in place of the ocular. By means of the lens "a" the field is focused in the plane of the slides and any portion singled out for examination. Because of diffraction phenomena the aperture should not be made less than $\cdot 5^{\mathrm{mm}}$ in diameter, but even with this restriction, and with the ordinary objectives, 3 or 4^{mm} focal length, grains not over $\cdot 01^{\mathrm{mm}}$ furnish good interference figures which ordinarily would be completely overshadowed and not discernible if adjacent light were not excluded.

FIG. 4.

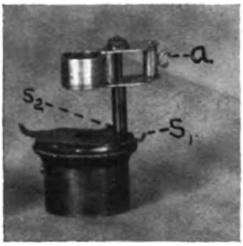

FIG. 4. Device for cutting down the field when interference figures from small grains are being observed as they form in the objective itself (Lasaulx method). Two sets, S_1 and S_2, of two plates at right angles and sliding in grooves permit the observer to cut off the light from any part of the field. Before observing the interference figure, the image from the objective is first brought to coincidence with the plane of the iris diaphragm by means of the field lens "a."

Experience has shown that the effects are still clearly recognizable if the diaphragm is at a distance of not over 5^{cm} from the eye, and for convenience sake, therefore, this diaphragm was inserted just below the ocular. The usual round disks with small aperture supplied with microscopes serve the same purpose but are less convenient.

Before stopping down the field by the diaphragm V just below the Bertrand lens, the image plane from the objective should on the same principle be brought to coincide with the plane of this diaphragm and the desired mineral section isolated by shutting off light from the adjacent grains. To accomplish this readily, a small lens, L, fig. 1a (19^{mm} focal length) has been introduced in the present microscope above the Bertrand lens, and in conjunction with the ocular serves the purpose of bringing to sharp focus the image picture in the plane of the Bertrand lens iris diaphragm, in accord with the principle noted above. In place of this small auxiliary lens, the writer has heretofore used a lens of long focal length and viewed the Bertrand lens diaphragm directly from the top of the tube. The new arrangement is more convenient, however, and obviates the necessity of removing the ocular before viewing the interference figure. The lens L swings on an axis and can be instantly thrown out of the field. A small spring with pointer automatically indicates the correct position of the lens when thrown into the field. The Bertrand lens diaphragm ordinarily supplied with microscopes is of little value in the observation of interference figures by the Lasaulx method without the use of the Bertrand lens, chiefly because of the disturbing effects of diffraction from the small apertures required and the distance of the aperture from the eye of the observer.

In designing this instrument, special attention has been paid to adjustment facilities and arrangements by which adjustments can be readily accomplished by the observer himself. In scientific instruments in general, too much reliance is often placed on the adjustment by the maker and the assumption "once in adjustment always in adjustment" notwithstanding jars and jolts of transportation, and the gradual relief of stress in any complicated mechanical system. Fortunately, the principle, which some manufacturers have adopted, of making all parts rigid and eliminating adjustment facilities, cannot be carried out in the construction of the microscope. In this instrument the axis of both the upper tube and the condenser holder on the microscope must coincide precisely with that of the revolving stage, in order that in every position the optical system remain centered. Since the ocular and the condenser remain automatically centered with respect to the revolving stage, while the objective changes its position slightly on each insertion, it is necessary that centering screws (a_1, a_2, fig. 1) be introduced for the objective itself and the direction of motion of centering should be parallel with the cross hairs of the ocular, as the eye estimates much more readily coördinate directions than diagonal directions. The principle sometimes adopted of placing the centering screws with directions of movement along the diagonals is therefore less favorable than along the cross hairs, and places a burden on the microscopist which might easily be avoided. The practice of placing the adjustment screws on the revolving stage instead of above the objective is wrong. The part of the optic system which is not in adjustment is the objective, not the stage. The axis of revolution of the stage should form the starting point for the adjustment of the whole instrument and should always remain fixed in its position. To this axis the ocular, condenser, and objective should be adjusted, and since the ocular and condenser remain practically stationary while the objectives are changed constantly, the only logical point of adjustment, to obtain satisfactory results, is above the objective.

To summarize briefly, the most important changes introduced on the present microscope are: (1) Both nicols revolve simultaneously, the connection between the two being a rigid bar, thus eliminating the errors due to lost motion in the gear-wheels of the systems ordinarily employed for this purpose. Since adopting the above device, the writer has learned that the scheme of revolving the nicols by a rigid connecting bar was used over thirty years ago by Dick in London, but was applied only to the revolution of a cap nicol above the ocular in conjunction with the polarizer. It was, therefore, slightly different from the present disposition. (2) The upper nicol always remains in the tube and the substage nicol is inserted or withdrawn on passing from ordinary light to crossed nicols. This device eliminates the annoying change of focus and shift of field ordinarily experienced when the nicol is inserted in the upper tube. (3) The sensitive plate is inserted just below the condenser and fits in a carrying device which is revolvable about the axis of the optical system. This disposition has been found convenient in determining the relative ellipsoidal axes in a plate, since the plate can be revolved more quickly and easily than the microscope stage or the two nicols together. (4) It has a new mechanical stage of novel design and simple but effective mechanical construction. The stage is practically dust-proof, has a free upper plate and a movement of 24^{mm} in any direction. (5) The Bertrand lens is fitted in a sliding device such that the magnification of the interference figure can be varied from 6·5 to 15·2 diameters. Immediately below the Bertrand lens, the iris diaphragm is introduced, while above this lens a second lens of short focal length can be thrown into the field which, together with the ocular, serves the purpose of focusing the image picture sharply in the iris diaphragm. (6) The second iris diaphragm at G, immediately below the ocular, is intended for use when observing interference figures directly by the Lasaulx method without the ocular and Bertrand lens. This iris diaphragm is a substitute for the device indicated in fig. 4, and the round cap plates usually furnished with microscopes, and although theoretically less satisfactory, practically it answers the purpose sufficiently well. (7) A large Abbe condenser is used, together with an Ahrens prism of 15^{mm} edge, or large nicol in place of the usual nicol and condenser with removable upper lens. This arrangement, first introduced on the Fuess microscope 1a, is a marked improvement over the usual arrangement and does away with the more or less complicated devices for removing the upper condenser lens from the optic axis of the microscope.

ART. XXXVII.—*A New Ocular for Use with the Petrographic Microscope*; by FRED. EUGENE WRIGHT.

MINERALS in the thin section are determined and recognized chiefly by the effects they produce on transmitted light and the relation of these effects to observed crystallographic features, such as cleavage, crystal form, etc. The usual optical properties which are thus made use of in determinative work are: crystal habit, cleavage, character of elongation, color, pleochroism and absorption, refractive indices, birefringence, extinction angles, optic axial angle, optical character, and rarely, dispersion of the optic axes.

These characters can be divided into two classes based on the methods of their determination. Those of the first-class (crystal habit, color, pleochroism and absorption, optical character of elongation, optical character of the mineral, and dispersion of the optic axes) are ascertained by direct observation without measurement, while for the second class (cleavage angles, extinction angles, optical axial angles, refractive indices and birefringence) numerical values obtained by actual measurement are required.

The ordinary petrographic microscope is adequate and satisfactory for the determination of the features included in the first class, but not for the second, if accurate data are desired. The result is that in petrographic determinative work and description these data are often only very roughly measured and are then expressed in general terms, such as "optic axial angle large," "birefringence strong," etc., without giving actual numerical data. The importance of quantitative measurements in all scientific work is obvious. The chief reason for the absence of the quantitative element in the major part of petrographic descriptions must, therefore, be sought in the cumbersome methods now available for the purpose. Thus a Babinet compensator, or other special device, is required for the measurement of the birefringence; a double screw micrometer ocular or Becke drawing stage for the measurement of the optic axial angle, etc. Believing that these various requirements can be met with sufficient accuracy by the use of a single ocular, which can be made to fit any ordinary microscope, the writer has had the present ocular constructed, which has proved satisfactory and convenient in actual use.* The ideas involved in this ocular are not new,† but the assembling of the different attachments into one ocular is novel and of sufficient general interest to warrant brief description.

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* This ocular was constructed by Fuess & Co. of Steglitz, Germany, (cost 200 mks.) and the writer desires to express his appreciation of the care taken by that firm in carrying out his suggestions.

† Compare F. E. Wright, this Journal (4) xxiv, 317-369, 1907; xxvi, 349-399, 1908; Journal of Geology, x, 33-35, 1902; Tscherm. Min. Petr. Mitteil., xx, 275, 1901. J. W. Evans, Min. Mag., xiv, 87-92, 1905.

The ocular is represented in fig. 1, and consists essentially of a metal holder, which is inserted in the microscope tube in place of the ordinary ocular and into which in turn a positive Ramsden ocular* is introduced at A and certain plates mounted in metal carriages, *a*, *b*, *c*, are inserted at B. Cross hairs are attached to the base of the tube A and are practically in the same plane with the upper surfaces of the sliding plates *a*, *b*, *c*, with the result that on focusing the Ramsden ocular on the cross hairs, the divisions marked on the plates *a*, *b*, *c*, are also in focus and their relative movements can be read off directly. With the above arrangement the optical constants required can be measured directly by means of the three plates.

Fig. 1.

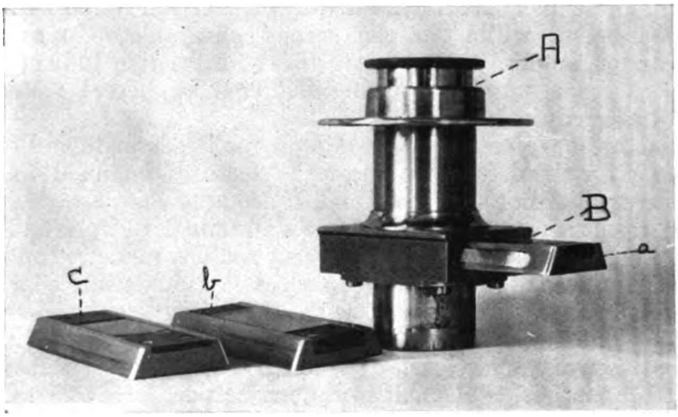

Fig. 1. New ocular with accompanying plates *a*, *b*, *c*, to be used in measuring the birefringence, the optic axial angle, and extinction angles of minerals in the thin section or in powder form.

Plate *a* (fig. 1, fig. 2a, b) is a combination quartz wedge† $35·3^{mm}$ long and 10^{mm} wide, and consists (fig. 2*a*) of a quartz wedge cut parallel with the principal axis (direction of elongation$=\mathfrak{c}$) $·5^{mm}$ thick at the thin end and $·89^{mm}$ at the thick end, its pitch being, therefore, about 6° 16′; and (2) of a quartz plate with direction of elongation $\mathfrak{a}$ of same length and width and $·56^{mm}$ thick. If these dimensions be followed exactly, 1/10 millimeter divisions ruled on the upper surface of the wedge (fig. 2*b*) will give directly the difference in distance in $\mu\mu$ between emergent light waves at a particular point. Thus, for sodium light the distance between successive interference bands will be $5{\cdot}89^{\mathrm{mm}}$. The zero line of the scale must coincide precisely with the black line of exact compensation between wedge and superimposed plate. In the present wedge this is the case; the slope of the wedge, however, is not exactly correct, and a slight correction must be applied to the readings obtained

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* An ordinary Huyghens ocular can also be used, provided the plates be inserted in the focal plane of the aplanatic eye lens.

† Compare F. E. Wright, Tscherm. Min. Petr. Mitteil., xx, 275, 1901; Jour. Geol., x, 33-35, 1902.

FIG. 2a.

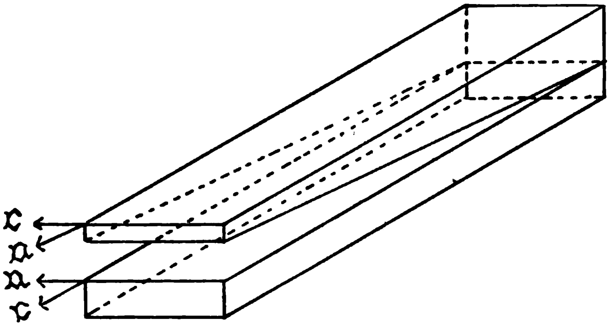

FIG. 2a. Combination wedge. Upper part of combination quartz wedge with direction of elongation=$\mathfrak{a}$, while lower part is a quartz plate, direction of elongation=$\mathfrak{c}$.

since 22^{mm} on the wedge is equivalent to $22{\cdot}62$ $\mu\mu$. For interference colors of the first and second order this error (nearly 3 per cent) is very slight and can practically be neglected, but for higher orders it must be taken into account and the readings multiplied by a factor of proportion. In actual work a table of equivalent values can be prepared or an inclined line of proper slope can be added to the color chart and the correct value equivalent to any observed value read off directly. With proper care, however, it is possible to grind these wedges correctly, so that the 1/10 millimeter divisions read directly in terms of differences in wave length ($\mu\mu$).

FIG. 2b.

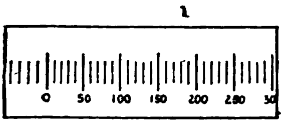

FIG. 2b. Top view of combination wedge showing divisions and position of dark line of exact compensation of wedge and plate. The $0{\cdot}1^{\mathrm{mm}}$ divisions on the scale are not represented in the figure.

In practice, the determination of the birefringence of a crystal plate in the thin section requires the determination of two distinct factors—the thickness of the crystal plate and the path difference between the emergent light waves. The thickness of the plate can be measured either by direct contact by micrometer screw or spherometer or by means of the fine adjustment screw of the microscope, or indirectly by means of the interference color or path difference of an adjacent mineral, properly cut and of known birefringence. Of these different methods the second is most convenient, although possibly less accurate. The usual method consists in bringing to sharp focus the upper surface of the plate and then the lower surface as seen through the plate itself, or if the plate be free along one side, to focus on the object plate on which the section is resting. In the first case, the apparent thickness must be multiplied by the refractive index of the mineral to obtain the true thickness. Since the average thickness of minerals in the thin section is about $\cdot030^{mm}$, an error of $\cdot001^{mm}$ in setting the micrometer screw will produce an error of 3 per cent in the thickness determination. In ordinary microscopes this error may frequently amount to ·002 or ·003, and the resulting error in thickness to 10 per cent.

Suppose the extreme limits of error be $\cdot003^{mm}$ or $\cdot0015^{mm}$ on either side of the true value, then an error of 5 per cent in the actual thickness determination may be considered probable. If this probable error be increased to 8 per cent to allow for multiplication by the refractive index and to introduce a safety factor, it can safely be assumed that the thickness of favorable crystal plates in thin sections, ranging from ·03 to $\cdot05^{mm}$ in thickness, can be determined readily by this method within 8 per cent of the true value. For minerals in powder form, the thickness of the individual grains may be much greater and the thickness determination correspondingly more accurate.

On the wedge whose scale divisions correspond to 10 $\mu\mu$ path difference of light waves, the error of determination is not over one division on the scale ($\cdot1^{mm}$), which is less than 2 per cent.

The total probable error of the determination of the birefringence of a mineral plate in the thin section in an unfavorable instance may amount, therefore, to 10 per cent. As the birefringence of the ordinary rock-making minerals ranges from about ·005 to ·050, an error of 10 per cent is confined to the third decimal place.*

In determining the birefringences $(\gamma-\alpha)$ or $(\gamma-\beta)$ or $(\beta-\alpha)$ of a mineral the position of the mineral plate (under examination)

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* An average of the birefringences of the 118 minerals listed under birefringence on page 292–295 of Rosenbusch-Wülfing, Micros. Phys. I, 1, gives ·040 as the mean value, while the value of the members midway between the two limits is ·020–·025. This value represents more nearly the mean value of the birefringence of rock-making minerals than the arithmetical mean, ·040.

FIG. 3.

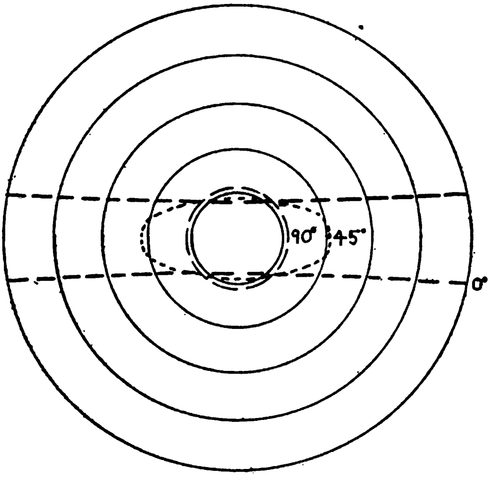

FIG. 3. In this stereographic projection plat (circles 10° apart) the positions of the directions in a biaxial crystal whose birefringence ($\gamma'-\alpha'$) is 2 per cent less than that of the optic normal ($\gamma-\alpha$) are indicated for the optic axial angles 2 V=0°, 45° and 90°. The optic normal coincides with the central point of the figure.

FIG. 4.

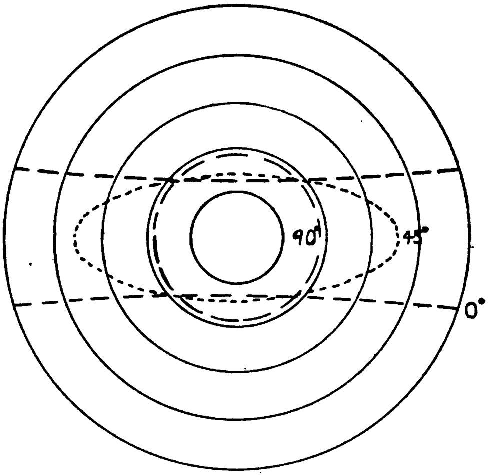

FIG. 4. Stereographic projection plat showing positions of the directions for which the birefringence ($\gamma'-\alpha'$) is 5 per cent less than that of the optic normal ($\gamma-\alpha$) which coincides with the center of the concentric 10° circles. These curves are drawn corresponding to the optic axial angles 2 V=0°, 45°, and 90°.

FIG. 5.

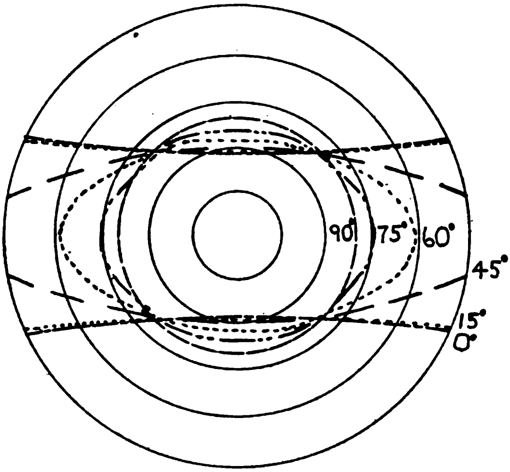

FIG. 5. Like fig. 4, except that the directions are indicated whose birefringence is 10 per cent less than that of the optic normal located at the center of the projection plat. The positions of the curves corresponding to optic axial angles 2 V=0°, 15°, 45°, 60°, 75°, 90°, are indicated in the figure.

FIG. 6.

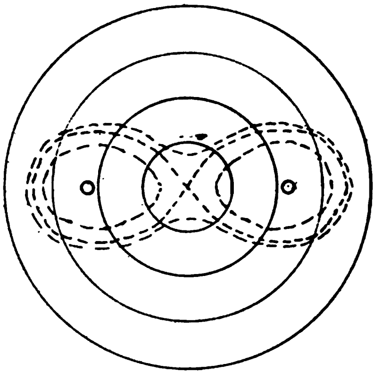

FIG. 6. In this figure the directions whose birefringence is 10 per cent less or greater than that of the acute bisectrix (optic axial angle 2 V=45°) are shown by the dotted curves. In this figure the dotted curve which passes through the center point (acute bisectrix) marks the directions whose birefringence is equal to that of the acute bisectrix (γ-β) or (β-a) as the case may be.

is ascertained by means of convergent polarized light. In actual work it is not always easy to find a plate cut precisely normal either to the optic normal or to one of the bisectrices, and it is of interest to know the percentage error caused by

FIG. 7.

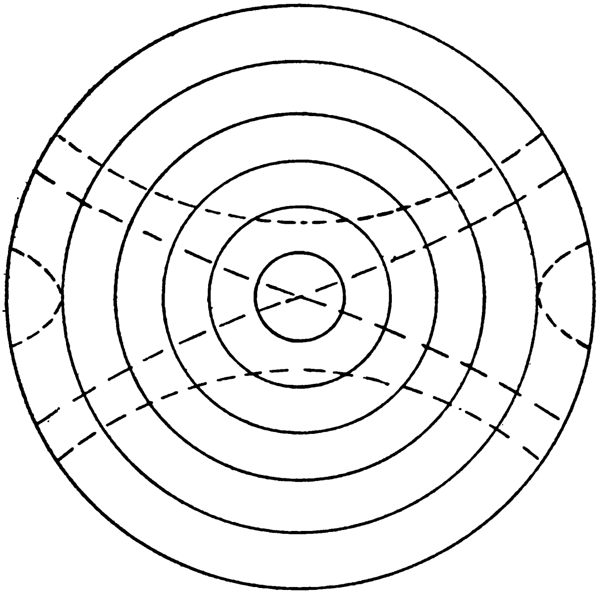

FIG. 7. Similar to fig. 6, except that the center of the projection plat is the obtuse bisectrix (2 V=45°). As in fig. 6, the directions whose birefringence is 10 per cent greater or less than that of the obtuse bisectrix are indicated.

FIG. 8.

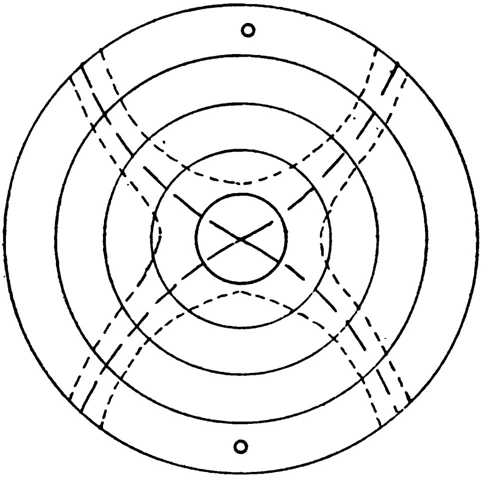

FIG. 8. Similar to fig. 6, except that the optic axial angle is 2 V=90°. The dotted curves again represent the directions for which the birefringence is 10 per cent greater or less than that of the bisectrix at the center of the projection plat. In this stereographic plat, as in all preceding, the concentric circles are 10° apart.

using sections inclined at low angles with the correct directions. For a given plate the birefringence can be calculated approximately from the usual formula,

$$\frac{\gamma'-\alpha'}{\gamma-\alpha}=\sin \mathrm{I}' \sin \mathrm{I}$$

in which I and I′ are the angles which the normal to the plate makes with the two optic axes (or optic binormals) respectively.

In figs. 3–8 these relations are shown graphically in stereographic projection. In each figure the angular distance between any two successive concentric circles is 10°. Thus in fig. 3 are indicated the positions of the sections whose birefringence is 2 per cent less than the true birefringence ($\gamma-\alpha$) exhibited by a properly cut plate exactly perpendicular to the optic normal. The position of these lines of equal birefringence is different for different optic axial angles as indicated by the lines for $2\ \mathrm{V}=0°$, 45° and 90°, but it is evident from the figures that an inclination of 10° with the true optic normal section will cause an error not over 2 per cent less than the true value ($\gamma-\alpha$) and often much less. In fig. 4 lines of equal birefringence 5 per cent less than the correct value ($\gamma-\alpha$) are drawn for different optic axial angles and show that inclinations of 15° produce errors of 5 per cent and less in the true value ($\gamma-\alpha$), while inclinations of 20° (fig. 5) produce errors of 10 per cent and less of the total birefringence. Similarly, for sections normal to a bisectrix, fig. 6 indicates that for an optic axial angle $2\ \mathrm{V}=45°$, a plate cut at an angle of 7° with the bisectrix may produce a positive or negative error of 10 per cent or less in the birefringence ($\gamma-\beta$) or ($\beta-\alpha$). But in this case the birefringence ($\gamma-\beta$) or ($\beta-\alpha$) is only about 14 per cent of the total birefringence, and an error of 10 per cent, therefore, usually applies only to the fourth decimal place. In fig. 7 the directions for which the birefringence is 10 per cent greater or less than ($\beta-\alpha$) or ($\gamma-\beta$), here about 85 per cent of ($\gamma-\alpha$) for $2\ \mathrm{V}=145°$ (obtuse bisectrix), approach within 18° of the bisectrix. In this figure, the curve indicating an increase of 10 per cent birefringence is 50° and over from the obtuse bisectrix. Plates making an angle of less than 20° with the bisectrix can, therefore, be safely assumed to furnish values of ($\beta-\alpha$) or ($\gamma-\beta$), which are not over 10 per cent in error. An inclination of 8° would produce an error of about 2 per cent in ($\beta-\alpha$) or ($\gamma-\beta$). In fig. 8, the rate of change of birefringence for sections at different angles with the bisectrix is indicated on the assumption that $2\ \mathrm{V}=90°$; there an inclination of 12° and over is required to effect a negative error of 10 per cent in the birefringence ($\gamma-\beta$) or ($\beta-\alpha$), and 18° or more to effect an equal, positive error.—Assembling these data, it may be assumed in general that the birefringence of a plate, inclined at an angle of 5–10° with the true direction (optic normal or bisectrix), will be in error about 2 per cent of the true value ($\gamma-\alpha$), ($\gamma-\beta$) or ($\beta-\alpha$); an inclination of 10–15°, about 5 per cent, while for 15°–20° inclination the error may be as much as 10 per cent of the true value desired. By means of the optic axial angle grating device described below, the angular inclination of the section can be ascertained and the probable error due to this cause thus eliminated.

In actual practice, therefore, the method of procedure in the determination of the birefringence of a mineral plate in the thin section or a mineral grain is to measure first the thickness by one of the methods noted above and then to insert the wedge "a" and determine under crossed nicols and in homogeneous (e. g. sodium) light, the path difference between the interfering light waves. For less accurate work the direct determination of the interference color and equivalent path difference indicated on standard color charts like that of Michel Levy is sufficient.—The actual error of such a determination should not exceed 10 per cent of the true value of the birefringence of the section. The probability of finding a section making an angle within 10° of a particular direction (optic normal) is about 1 in 66; and a section within 20° about 1 in 16. Since wedge "a" is merely a refined combination wedge, it can be used for all purposes for which the latter serves.

Fig. 9.

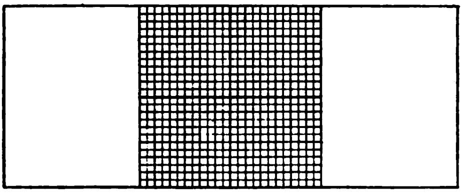

Fig. 9. Top view showing cross grating ruling on plate *b* used in the measurement of optic axial angles of mineral plates in the thin section. In this figure, the $0{\cdot}5^{mm}$ divisions are indicated but not the $0{\cdot}1^{mm}$.

(b) Plate *b* (fig. 1 and fig. 9) and the measurement of the optic axial angle.—By the use of this device, which is simply a thin glass plate $1{\cdot}5^{mm}$ wide, on which fine coördinate lines $0{\cdot}1^{mm}$ apart have been ruled, the optic axial angle of a mineral can be measured, provided one or both optic axes appear within the field of vision. The principles on which the method is based are considered in detail in a former paper.[*]

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[*] The Measurement of the Optic Axial Angle of Minerals in the Thin Section, this Journal (4) xxiv, 317-369, 1907; also, Das Doppel-Schrauben-Mikrometer-Okular und seine Anwendung zur Messung des Winkels der optischen Achsen von Kristalldurchschnitten unter dem Mikroskop, Tscherm. Min. Petr. Mitteil., xxvii, 293–314, 1908.

There the different methods for measuring the optic axial angle are treated at length, especially those of Mallard, Becke and Fedorow, together with a new method which requires for its application a double screw micrometer ocular or a cross grating ocular like plate b (fig. 9). The method of procedure for both double screw micrometer ocular and cross grating ocular is the same,—the observed coördinates being first reduced to equivalent angular values, and these in turn, after reduction to values obtaining within the crystal, plotted in stereographic projection in order that the axial angle values may be found graphically. In the article mentioned the different steps requisite for this method are described at length and need not be repeated here. By means of this ocular, with ruled cross section slip, the optic axial angle of a favorable section on which both optic axes are visible can be determined within

Fig. 10a.

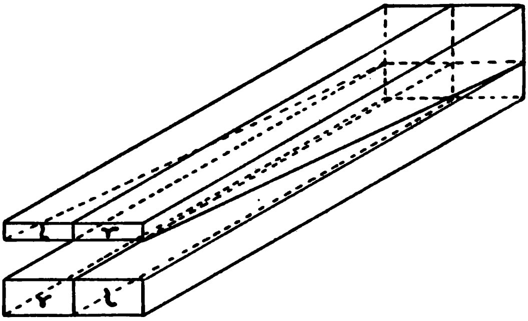

Fig. 10a. View of bi-quartz wedge plate showing relative positions of right and left-handed wedges and underlying left and right-handed quartz plates, all normal to the optic axis, and in combination forming the most sensitive device for the determination of the exact position of total extinction of minerals in the thin section. To be used also in adjusting the nicols in the petrographic microscope.

Fig. 10b.

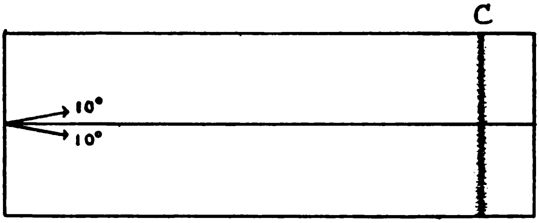

Fig. 10b. Top view of bi-quartz wedge plate. The position of dark line of zero rotation or exact compensation is indicated at C.

1–2°. If only one optic axis appears within the field, an error of ±3° is possible on even a favorable section.

(c) Plate *c* (fig. 1 and fig. 10a and b), bi-quartz wedge plate for the accurate determination of extinction angles.—The principles and methods for determining extinction angles are presented at length in another paper,* where it is shown that for general purposes with variable light conditions and varying sensitiveness of the eye, a satisfactory general method should possess an element of adjustable sensibility in order to meet best the different conditions. This was found to be realized most satisfactorily in the bi-quartz wedge plate. The present plate was made after the following specifications: (fig. 10a) Wedge of right-handed quartz, length 35·3^{mm}, width 6^{mm}, thickness at thin end 35^{mm}, at thick end ·85^{mm}; plate of left-handed quartz, length 35·3^{mm}, width 6^{mm}, thickness ·4^{mm}; thin plate to be cemented on the wedge to a combination plate wedge which gives zero extinction at a distance 3·5^{mm} from the thin end. The same specifications to be followed with a wedge of left-handed quartz and a plate of right-handed quartz, likewise superimposed and cemented side by side as indicated in the figure and in such a way that the line of total extinction in the first combination is the extension of the line of zero extinction in the second (C in fig. 10b). This wedge in sodium light gives at the extreme end symmetrical extinction of about ±10° (fig. 10b), while at the thin end it is ±1°.

The position of darkness between crossed nicols for any plate is tested by simply inserting the bi-quartz wedge plate and observing the effect on the adjacent halves of the plate. If the position of total extinction coincides precisely with the planes of the nicols, both sides of the wedge will show the same intensity of illumination on insertion. If this is not the case, the observed plate must be revolved again and the test repeated. With this method on favorable sections the position of total extinction can be determined on a single trial within 10′.

The determination of an extinction angle on a mineral plate involves two distinct steps—the location of the exact position of total extinction and the angular relation (optical system, accurately centered) of this direction to some observed crystallographic direction, as crystal edge or cleavage line. The error of the latter determination is not great since the eye is sensitive to errors in parallelism of adjacent lines as cross hair line and cleavage line. The measurement of the extinction angle by simply revolving the stage and thus determining the position of total extinction, is sufficiently accurate for ordinary purposes, if the average of a number of determinations be taken, and for ordinary petrographic work the expensive bi-quartz wedge might possibly be omitted altogether. The time saved, however, by its use in accurate work is a factor which would soon offset the expense involved.

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*On the Measurement of Extinction Angles in the Thin Section, this Journal (4), xxvi, 349–390, 1908.

For the adjustment of the petrographic microscope the bi-quartz wedge plate is also well adapted.*

With the three plates, *a*, *b*, *c* (fig. 1), accompanying this ocular, it is therefore possible to determine with sufficient accuracy the birefringence, the optic axial angle and extinction angles of mineral plates in the thin section. There remains still the determination of the refractive indices, and no satisfactory method has yet been devised for the accurate determination of these on plates in the covered thin section. On the polished thin sections the refractometer attachment of of Wallerant has proved satisfactory, while for minerals in fine grains or powdered sections the immersion method in liquids of known refractive index is best adapted. By this method, the refractive indices can readily be obtained on favorable sections with a probable error of about ±·002.† By such direct refractive index measurement, birefringence determinations and optic axial angle measurement can be checked and possible errors eliminated.

Summary.

With the ocular pictured in fig. 1, three fundamental optic properties of minerals in the thin section can be measured. (1) With the combination wedge "a" the birefringence; (2) with the ruled plate "b" (cross section ruling interval ·1^{mm}) the optic axial angle, provided one or both optic axes appear within the field of vision; (3) with the bi-quartz wedge plate "c" the extinction angle. These three features, and particularly the first two, are usually estimated only roughly and not measured accurately in petrographic work, chiefly because of the complicated apparatus now required for the purpose. The present ocular was constructed to serve as a simple but effective substitute for such apparatus, and thus to facilitate the actual measurement of these important properties. In the same holder other wedges and plates can be introduced which may serve for the determination of the above and other optical properties of a crystal plate.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., January 31, 1910.

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* F. E. Wright, this Journal (4), xxvi, 386-388, 1908.

† Compare O. Maschke, Pogg. Ann., cxlv, 568, 1872 ; Wiedemann's Ann., ii, 722–734, 1880 ; J. Thoulet, Bull. Soc. Min., Fr., iii, 62-68, 1880 : J. L. C. Schroeder van der Kolk, Zeitschr. f. Wiss. Mikroskr., viii, 458, 1892; F. E. Wright, this Journal (4), xxvii, 385-387, 1907; Tscherm. Min. Petr. Mitteil., xx, 239, 1901.

Art. XXXVIII.—*On the Behavior of Crystals in Light Parallel to an Optic Axis;*[*] by Charles Travis, Ph.D.

If a section of a biaxial crystal be cut normal to an optic axis, and this section examined in parallel light between crossed nicols, it appears uniformly bright in all positions when rotated about the axis. This is commonly ascribed to interior conical refraction, the explanation given by various authorities[†] being the equivalent of the following:

When a ray of light, the wave-front of which is normal to the optic axis, enters the section, it is broken up into a cone of rays, each element of which is polarized in a different plane. Hence the light on emerging is polarized in all azimuths. This is equally true if the entering ray is plane polarized, for its vibration will have a component parallel to the vibration direction of each elementary ray of the cone. No matter how the analyzing nicol is placed with respect to the polarizer, then, it will fail to extinguish all the light that comes from the crystal. Following out this line of reasoning, it appears that the intensity of the light passing the upper nicol will be one-half of that from the lower.

Certain important factors are neglected in reaching this conclusion, which is untenable when these are considered. It is, therefore, the object of this paper to present a discussion of the behavior of crystals in light that is approximately parallel to an optic axis, and to explain the observed differences between uniaxial and biaxial crystals under these conditions.

§1. In any pencil of light that it is possible to obtain in practice, there are rays having all directions within certain limits. The energy of those rays that are strictly parallel to a given direction (e. g., the optic axis) is infinitesimal compared to the total energy of the pencil. An example will make this clear. Suppose our source of light is a circular area of radius, r, at the focus of a collimating lens of focal length, f. The angular radius of the pencil is then equal to the angle whose tangent is $\frac{r}{f}$. A line drawn through the optical center of the lens, parallel to the optic axis, will intersect the source in a point, p, and from this point *only* do we obtain rays that are parallel to the axis. The area of the point p is obviously zero compared to the total area of the source, no matter how small we may make the latter.

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[*] This paper was suggested by the work of W. Voigt (referred to below), who shows that interior conical refraction has no practical existence. The writer's chief object is to point out the correct explanation of a phenomenon that is well known to crystallographers.

[†] For example, cf. Groth, P., Physikalische Krystallographie, Leipzig, 1905, p. 109.

It appears from this that interior conical refraction is a purely mathematical ideal, never attained in practice. Yet it is a well-known fact that a small source of light (a pin hole), viewed along the optic axis of a biaxial crystal, appears not as a double image, but as a luminous ring. Voigt* has shown that what is observed in this case is not interior conical refraction, but simply an approximation to it. His reasoning may be summarized as follows:

A hollow cone of rays, of very small angular radius a, and surrounding the axis, traverses the crystal in two hollow cones of radius, $\frac{\phi_1}{2} \pm a$, where ϕ_1 is the angle of the cone of interior refraction. A solid cone of rays, of the same angular radius, will traverse the crystal under the same conditions in the annular space included between the two cones of radius $\frac{\phi_1}{2} \pm a$. If, however, we consider not the summation of the effects produced upon a cone of rays, but the effect upon any individual ray, we see that this ray undergoes simple double refraction, and traverses the crystal in two definite rays. In other words, there is no essential difference between the behavior of rays near the axis and that of those at an appreciable distance from it.

§2. Plane polarized light is split up, by passage through a biaxial crystal, into two sets of rays, vibrating at right angles. The components of these vibrations, in any one plane (obtained by placing the analyzing nicol above the crystal), produce certain definite interference effects. From the foregoing, light in the neighborhood of the optic axis forms no exception to this; but as the divergence of the two complementary rays is often a maximum near the optic axis, it is well to consider the effect produced by having the source of light at a finite distance from the section.

A ray SA (figure 1), from a source S, is divided, upon entering the crystal, into the rays AB and AC, which vibrate at right angles. From the same source, another ray, SD, may be found, which will divide into DC and DE; C is then the common point of emergence of one ray from each of the points A and D. These rays are polarized at right angles. If the crystal is between crossed nicols, interference takes place between the components of AC and AD, parallel to the plane of the upper nicol. The effect produced is dependent upon the difference in phase at C, and this is due to the difference in the optical length of the paths SAC and SDC.

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* Voigt, W., Ann. Phys., xviii, 1905, p. 645.

Let us assume that the wave-front of the two rays is essentially normal to the optic axis, so that the *front* velocity (not *ray* velocity) is the same for each, and is equal to $\frac{1}{\beta}$; let MN be the direction of the wave-front in the crystal and M′N′ that outside the crystal; also let SA be very large compared to AD. In the crystal, the path difference is β. AD. sin MNN′, AC having the longer path. Outside the crystal, the path difference is AD. sin M′N′N, SD having the larger path. But sin M′N′N$=\beta$. sin MNN′; therefore SAC is optically equivalent to SDC.

FIG. 1.

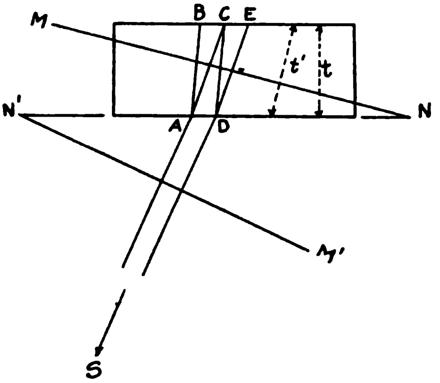
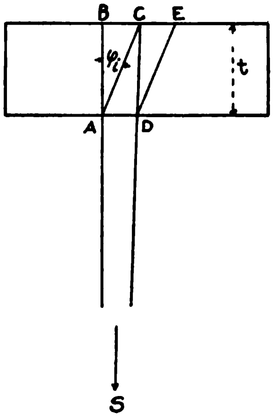


FIG. 2.



If, then, S is at a great distance, the two rays at C will be in phase; their vibrations will give a resultant which is parallel to the plane of the lower nicol, and this resultant will be extinguished by the upper nicol.

In discussing the case in which the source is at a finite distance, the condition that the section be taken normal to the axis is assumed temporarily. (Figure 2.) The maximum phase difference is that between the two rays that lie in the plane of the optic axes; in the figure, this plane is taken as the plane of the paper.

Let $\Delta\gamma$=the path difference, SD−SA. (AC and DC are optically the same.)

D=the distance of the source, SA.

ϕ_1=the angle of the cone of interior conical refraction.

$$\text{Then } \Delta\lambda = \frac{\overline{AD}^2}{2D} = \frac{(t \tan \phi_1)^2}{2D}.$$

$$\therefore \quad \Delta = \frac{(t \tan \phi_1)^2}{2D\lambda}.$$

For other pairs of rays in the plane of the axes, the relative lengths of SA and SD are changed, but the phase difference Δ at the point of interference is constant if the rays are so nearly parallel to the axis that their front velocity in the crystal may be considered constant. The reason for this is evident upon reference to fig. 1 and the accompanying discussion.

When the section is not cut normal to the optic axis (as in figure 1), it can be shown that the above results hold if t', the thickness parallel to the axis, be substituted for t.

For equally thick sections, with the source of light at a constant distance, the maximum phase difference Δ, due to the cause considered above, depends upon tan ϕ_1. The value of ϕ_1 for aragonite is 1° 50′, which is exceeded in very few other substances; the greatest known value is that for sulphur, for which $\phi_1 = 7°$ approximately. Approximate values of Δ for sections of sulphur and aragonite, with D assumed as one meter, and λ as $0{\cdot}0005^{\text{mm}}$, are as follows:

Sulphur		Aragonite	
t (mm.)	Δ	t (mm.)	Δ
10	1·0	10	0·1
5	0·25	5	0·025
1	0·01	1	0·001

We may conclude from this, that with the source of light at distances commonly used when working with the polarizing microscope, Δ becomes practically zero in the very great majority of cases. (This assumes that the condensing system is removed from the polarizer.) Any illumination that is observed between crossed nicols is, therefore, due to the fact that the direction of the light is so inclined to the optic axis that one ray is appreciably retarded with respect to the other, in traversing the crystal. In other words, *the behavior of the crystal in light that is approximately parallel to an optic axis, must be referred to interference effects of exactly the same nature as those observed in any general section, with the light falling at any inclination to the axis.*

§3. The relative amount of light that a crystal section will transmit, when examined between crossed nicols, may be determined by means of the interference figure given by the same section in convergent light. This figure is virtually a spherical projection, in which each point represents a ray direction: if a is the angle between a given direction and the line of collimation of the instrument, the point that represents this direction will lie at a distance from the center of the figure proportionate to sin a. The pencil of light that falls upon the section consists of rays having all directions within certain limits; if in any given pencil the maximum divergence between rays is $2a$, a circle drawn upon the interference figure, with radius proportionate to sin a, will represent the limits of the pencil. The average intensity of that portion of the figure lying within the circle is obviously equal to the relative amount of light transmitted by the section, when this is illuminated by the pencil under consideration.

The intensity at any point of the interference figure may be found from the following equations:*

$$I = \sin^2 2\theta \,.\, \sin^2 \pi\Delta \qquad (1)$$

$$\left.\begin{array}{l} \Delta\lambda = F\rho \sin\phi_1 \sin\phi_2 \\ F = \dfrac{\dfrac{1}{2}\left(\dfrac{1}{\alpha^2} - \dfrac{1}{\gamma^2}\right)}{\left[\dfrac{\dfrac{1}{\alpha^2} + \dfrac{1}{\gamma^2}}{2}\right]^{\frac{3}{2}}} \end{array}\right\} \text{(For biaxial crystals.)} \qquad (2)$$

$$\left.\begin{array}{l} \Delta\lambda = F\rho \sin^2\phi, \\ F = \pm \dfrac{\dfrac{1}{2}\left(\dfrac{1}{\omega^2} - \dfrac{1}{\epsilon^2}\right)}{\dfrac{1}{\omega^3}} \end{array}\right\} \text{(For uniaxial crystals.)} \qquad (3)$$

Equation (1) gives the relative intensity I at any point of the figure, in terms of the phase difference Δ between the two sets of interfering rays projected in that point, and the angle θ that the vibration planes of these rays make with the planes of the nicols. In equations (2) and (3), which give us Δ, ρ is the thickness of the section measured along the wave-front normal of the rays, ϕ_1 and ϕ_2 the angles that this normal makes with the two optic axes in a biaxial crystal, and ϕ the angle that it makes with the single axis in a unaxial crystal. In both cases F is a function of the principal indices of refraction; if $(\gamma - \alpha)$ for a biaxial crystal is equal to $\pm\ (\omega - \epsilon)$ for a uniaxial one, F will not be very different in the two cases.

Near the optic axis, (2) may be written

$$\Delta = \frac{F\rho}{\lambda} \,.\, \phi_1 \sin 2V$$

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* Liebisch, Th., Grundriss der physikalischen Krystallographie, Leipzig, 1896, p. 273, 336, 375. The above forms for the equations are somewhat different from those given by Liebisch.

or, dropping the subscript,

$$\phi = \frac{k\Delta}{\sin 2V} \tag{4}$$

2V being the angle between the optic axes, and k a small constant. Under the same conditions, (3) may be written

$$\phi = \sqrt{k\Delta} \tag{5}$$

Hence in the figure given by either kind of crystal, the loci of points of equal phase difference Δ are concentric circles. When Δ is an integer, the factor $\sin^2\pi\Delta$ in (1) vanishes; when Δ is an odd number of times one-half, $\sin^2\pi\Delta$ attains its maximum value, which is unity. The dark circles around the axis are the loci of points for which Δ is equal to n, and the bright ones those of points for which Δ is equal to $n-\frac{1}{2}$, n being an integer.

It is evident that the average intensity of the portion of the figure included in a circle whose center is the axis, increases with the size of the circle until this coincides with the first ring of maximum brightness; after this the average intensity fluctuates, but undergoes no great change. If, then, a crystal section is illuminated by a pencil of angular radius r, the intensity of the light transmitted is zero when r is zero, increases with r until r is equal to the radius of the first bright ring, and is approximately constant as r increases beyond this.

The only important difference between biaxial and unaxial crystals, in this regard, lies in the difference between the radii of the first bright rings in the two cases. If the birefringence and the thickness of section are the same for both, k (equations (4) and (5)) has roughly the same value for either kind of crystal. But the radius of the first bright ring for the biaxial crystal is

$$\phi_b = \frac{\frac{1}{2}k}{\sin 2V}$$

whereas for the uniaxial crystal it is

$$\phi_u = \sqrt{\tfrac{1}{2}k}$$

and if k is very small (as it commonly is), ϕ_u is much larger than ϕ_b.

This is well shown by comparing sections 1^{mm} thick of aragonite and calcite. It is to be noted that while calcite has the greater birefringence, the first bright ring for this substance is six times as large as that for aragonite. In the calculation,* sodium light is assumed, for which $\lambda = \cdot000589^{mm}$.

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* The radii of the circles of maximum and minimum intensity are calculated as they appear after refraction from the crystal into the air.

Aragonite

$\alpha = 1{\cdot}5301$
$\beta = 1{\cdot}6816$
$\gamma = 1{\cdot}6859$
$2V = 17°50'$
$(\gamma-\alpha) = 0{\cdot}1558$
$\log k = 7{\cdot}58012$

Calcite

$\omega = 1{\cdot}6585$
$\epsilon = 1{\cdot}4863$
$(\omega-\epsilon) \doteq 0{\cdot}1722$
$\log k = 7{\cdot}46201$

Aragonite: Radii of bright rings	Aragonite: Radii of dark rings	Calcite: Radii of bright rings	Calcite: Radii of dark rings
0° 36′		3° 37′	
	1° 12′		5° 07′
1 48		6 17	
	2 24		7 15
3 00		8 07	
	3 36		8 54

§4. The maximum divergence of so-called parallel light is often considerable, as a simple calculation will show. The lowest power objective (No. 0) that is furnished with the Fuess No. 3 microscope has a focal length of about 42^{mm}; its working distance was found to be $38{\cdot}2^{mm}$, its aperture, $6{\cdot}8^{mm}$, and its field, $4{\cdot}8^{mm}$ in diameter. From this, its angular aperture is 17° 30′ approximately, and when the low power lens that is furnished with the polarizer is in place, the objective works at this full angle. By removing this condensing lens, the effective aperture is considerably diminished, becoming approximately 7° 30′; this may be reduced to 6° 30′ by the substage diaphragm. Only by decreasing the size of the source of light, or by increasing its distance, can we obtain light that has less divergence than this. A source 1^{cm} in diameter, at a distance of 1 meter, for example, gives with the above objective a pencil whose angle is roughly 1°.

By comparing these values with the diameter of the first bright ring for aragonite, the reason is apparent for the brightness of a section of this substance, cut normal to an axis, of appreciable thickness. It is evident that a basal section of uniaxial calcite, 1^{mm} thick, should also be bright when examined with the above objective, even without the substage condensing lens; experiment verifies this.

The dark brushes of the interference figure, that mark the points for which the factor $\sin^2 2\theta$ (in (1)) approaches zero, widen out as the distance from the axis increases. At an appreciable distance from the axis, a small circle, centrally located in a brush, has an average intensity that is practically zero. This is the reason why a biaxial crystal, placed so that its axial plane coincides with the plane of one of the nicols, and rotated in this plane, is dark except in those positions in which an axis is approximately vertical.

In the above discussion, the light in every case is assumed to be monochromatic. When white light is used, we must consider two additional factors.

(1). The size of the rings in the interference figure increases with the wave length of the light; the average intensity for a pencil concentric about the axis is therefore dependent upon wave length. If the pencil is small, we may say that with light of a *greater* wave length, *less* is transmitted.

(2). In biaxial crystals, the dispersion of the optic axes renders it impossible to center a pencil about the axis for light of more than one wave length.

The total result of these two factors is that the intensity of the illumination varies with its color, and the crystal in white light, which is approximately parallel to an optic axis, shows impure interference colors.

Summary.

In regard to the observed fact that a section of a biaxial crystal, cut normal to an optic axis, is uniformly bright between crossed nicols, we may conclude that:—

(1). Interior conical refraction, in a strict sense, plays no part whatever as a cause of the phenomenon.

(2). The cause is to be found in the fact that so-called parallel light has commonly a considerable divergence.

(3). In any given case, the observed intensity of illumination is equal to the average intensity of that portion of the interference figure bounded by the limits of the pencil of light used. The general configuration of the interference figure is dependent upon the optical constants of the crystal, and upon the thickness of section; these, as well as the amount of divergence of the light, are the determining factors.

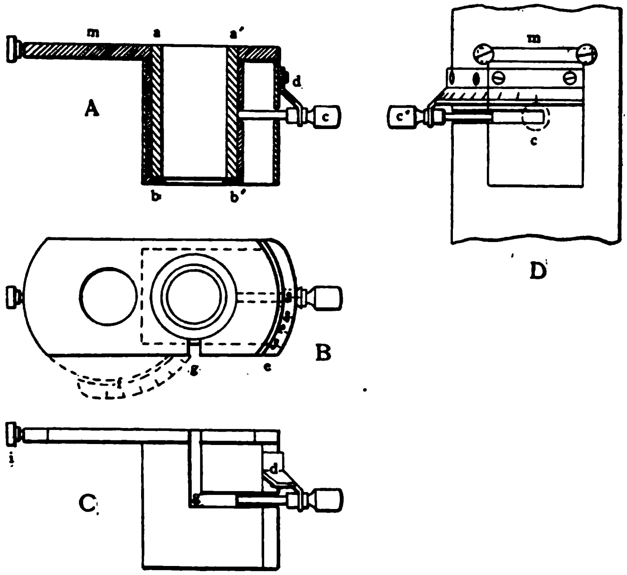
(4). The reason why the same phenomenon is not commonly observed in uniaxial crystals, is that in the uniaxial figure the first bright ring about the axis is in general much larger than that in the biaxial figure. Under proper conditions, however, the phenomenon may be also shown by a uniaxial crystal.

University of Pennsylvania, January, 1910.

Art. XXXIX.—*Some Simple Improvements for a Petrographical Microscope;* by Albert Johannsen.

1. A rotating upper nicol in which the annoying reflection of light from the surface is overcome.—In examining, between crossed nicols, minerals which are rather dark, a small amount of light falling upon the upper surface of the nicol produces a hazy appearance of the image. Figure 1 represents a light-tight modification of the upper nicol of the Fuess III–*a* microscope. A vertical section through the carriage is shown at A. A rotating collar (*a a'*) is moved by the lever *c* and is supported by the flanges *b b'* of the outer tube in which it rotates. A part of the scale (*d*) is attached to the box and is divided into degrees, although only the 10° divisions are shown at B.

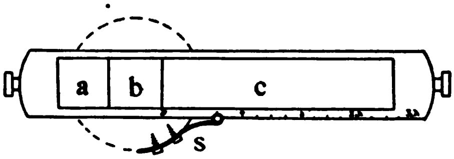
Fig. 1.



B and C are respectively the horizontal and the vertical projection. The separation of the scale into two parts, which was made necessary by its lowered position, is shown at *e* and *f*. The slot *g*, which is also shown in figure 1–C, is for the easy removal of the nicol from the carriage. The prism is rotated 90° and is lifted out, after the entire carriage is taken from the tube of the microscope, by the removal of the screw *i*. Figure 1–D is an end view showing how the plate *m* entirely closes the upper part of the opening in the tube and prevents all reflection from the surface of the nicol. The lever *c* is shown at *c′*, rotated through 90°.

2. A permanently attached combination wedge.—A great deal of time is ordinarily lost in picking up the accessories to the microscope and in hunting for the slot into which they are to be inserted. The simple contrivance shown in figure 2 has been found to overcome all this. A carriage, exactly fitting the slot above the objective, is inserted in the tube of the microscope and is kept in place by two end screws like those holding the Bertrand lens bar. At one end is a square of gypsum (*a*) giving red of the first order; *b* is an opening; and *c* is a quartz wedge underlain by a mica plate, the two minerals having their c directions at right angles to each other, and similar in construction to a Wright quartz gypsum-wedge. The thickness of the underlying mica plate is so chosen that it exactly compensates the front end of the quartz wedge, consequently the colors of the combination wedge begin at darkness and gradually increase to the fourth order as the wedge is shoved forward. A spring (S) attached to the side of the microscope tube presses against the carriage and produces enough friction to hold it wherever it is placed. When the opening *b* is centered, the spring drops into a rounded notch as shown. Upon the upper side of the carriage a scale is engraved and the end of the spring shows the order of the color at that time beneath the cross hairs of the microscope.

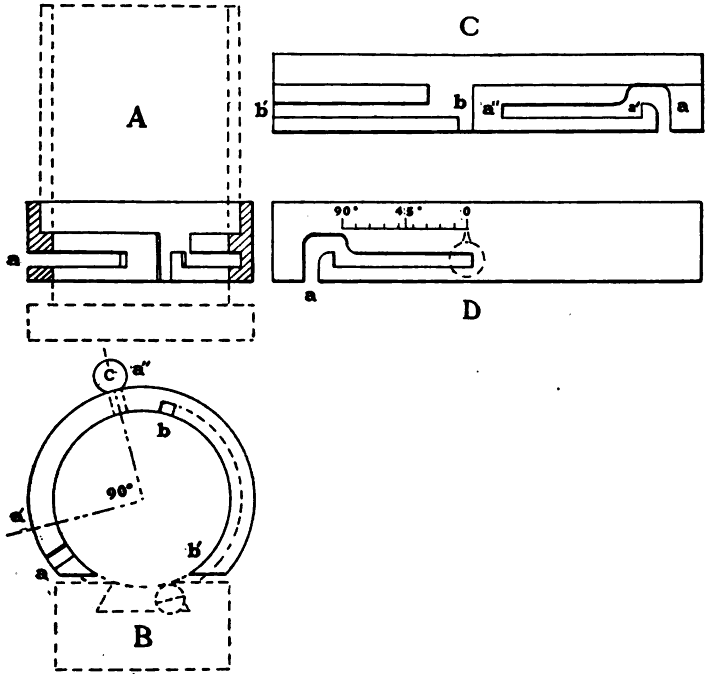
Fig. 2.



3. A rotating lower nicol for observing very slight pleochroism.—In the ordinary petrographical microscope, such as the Fuess III-*a*, which is the one generally used, the arrangement for rotating the lower nicol is extremely crude, and the force necessary to overcome the friction by which it is retained in place makes smooth rotation impossible. In order to observe very slight pleochroism, it is often desirable to turn the nicol instead of the stage; the movement of the mineral in the latter case causes confusion and makes it impossible to observe very slight changes of color. Nor is it possible to obtain the same results by removing the lower nicol and rotating the upper nicol in its place, for a distortion of the image results and consequently, also, a movement of the lines. For this reason the arrangement described below has been found very effective.

A brass collar was turned to fit the lower part of the nicol tube and was soldered on as shown in figure 3. A section through the collar is shown at A, figure 3; the nicol tube being here

FIG. 3.



indicated by dotted lines. B is a view from below; C, a view of the inside of the collar as it would appear if straightened out; and D, the outside of the collar similarly unrolled. A groove is cut on the inside to receive the head of a screw projecting from the side of the nicol tube (*b b'*, fig. 3, B and C). On the opposite side of the tube, a lever (*c*) moves in the slot *a a''* (fig. 3, B), which is of such length that the distance between centers of the lever, in the positions *a' a''*, is just 90°. The screw head and the lever bar thus form the bearings to carry the nicol tube. As the lever is moved from *a'* to *a''*, the screw head *b* slides in the groove from *b* to *b'*. (As a matter of fact this groove was turned the entire circumference of the collar, for convenience of construction, though it is not so shown in the diagrams.) The nicol tube may be removed or inserted easily by slightly raising and rotating the tube until the lever bar passes over the projection at *a* (fig. 3, D).

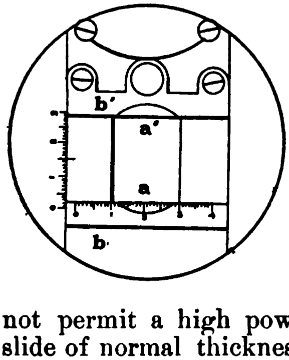
In the microscope as purchased, the nicol is held in place by the pressure of a part of the tube between two saw cuts. Before attaching the collar, this pressure arm is cut off just above where the upper edge of the collar is to come, and the upper part is bent outward until only enough friction remains to hold the nicol in any position to which it may be turned. It is necessary to saw off the lower part of this section in order that the upper part may later, if necessary, be bent more or less to produce the proper amount of friction. On a new instrument the cut would be made only above. The collar is soldered on the tube so that the nicols are approximately crossed when the lever is set at 0°. Accurate adjustment may later be made by rotating the prism within the tube.

In the Fuess microscope with rotating upper nicol, the vibration plane is at right angles to the direction of the lever, and the indicator points to 90° on the scale. Consequently, the upper and lower scales have readings differing by 90° when the nicols are crossed, and have the same readings when they are parallel.

In using certain accessories it is sometimes necessary to place the ocular so that the cross hairs form angles of 45° with the vibration directions of the nicols. With a microscope fitted as above, both nicols may be rotated to 45° and the ocular left in its normal position.

4. Additions to the Hirschwald stage.—Figure 4 shows two scales engraved upon the two parts of the Hirschwald stage. A mark on the sliding portion indicates the distance through which the plate has been moved. Horizontal movement is registered by a small scratch made with a diamond point on the lower margin of the thin section. Any mineral, whose position is once registered, may again be located by resetting the stage to the former reading. By reading first the vertical and then the horizontal scale, the stage setting shown in the diagram is indicated by the figures "1·5-2·0" (if the scratch on the slide is at the letter *a*).

FIG. 4.



The stage, as made at present, does not permit a high power objective to be brought close to a slide of normal thickness when the mineral is near either of the clamping bars (*b*, *b'*). The bars should be beveled slightly at *a* and *a'*. In a corresponding position on the under side, enough of the sliding stage should be cut away to permit the condensing lens to be carried against the slide at its edges as well as at the center.

The University of Chicago, February, 1910.

Art. XL.—*A Natural Naphtha from the Province of Santa Clara, Cuba;* by Clifford Richardson and Kenneth Gerard Mackenzie.

The occurrence of colorless naphtha as a natural product in Santa Clara is not new. It was first encountered August 18, 1881, in the western part of the Province near the town of San Jose de los Ramos, at a depth of 300 feet. Its special characteristics were, according to Salterain[*]: "It is colorless, transparent as the clearest water, easily inflammable, and leaves no sensible residue after its complete combustion; its density is 0·754; it boils at a temperature of 85°, dissolves asphaltum and resinous matter, and possesses the characteristics of naphtha." Sr. Manuel Cueto, the discoverer, reports that it was used with good success in the engine of a steam launch and as motive power for automobiles. About 20,000 gallons were obtained, but disasters, breaking of drills, etc., caused the enterprise to be abandoned, and the buildings were destroyed during the war. The wells were visited in 1902 by a Canadian driller. He reported that they were not producing, but that considerable gas was being evolved. Oil was found 300 feet down, which had a gravity of 61·6°B. The rock, through which the wells were drilled, was a limestone mixed with a black quartz. About 180 feet below the surface, a rock resembling serpentine was encountered.

The oil described in this paper comes from the same general locality, at a depth of 1560 feet. The overlying strata as shown by the drilling records were as follows:

Depth		Kind of Rock
18	feet	Red soil.
44	"	Yellow clay.
50	"	Hard black rock.
52	"	Flint, gravel and pyrite.
58	"	Loose bowlders.
80	"	Bowlders and gravel.
85	"	Pyrite.
88	"	Pyrite and sand.
94	"	White quartz.
96	"	Coral rock.
101	"	Sand.
108	"	Hard dark sand.
118	"	Pyrite.
124–128	"	Sand.
128–134	"	White limestone.

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[*] U.S. Consular Report, vol. x, p. 75, 1883, cited by Wood, Civil Report of Military Gov. Cuba, Jan. 1, May 20, 1902, vol. v, pt. iii, p. 82.

Depth		Kind of Rock
134–154	feet	Black slate and white limestone.
166–176	"	*Green serpentine.*
176–194	"	Limestone and slate.
208–242	"	Black slate.
302	"	Soapstone.
347	"	Green serpentine.
425	"	Green serpentine and soapstone.
550	"	Dark slate.
565	"	Hard black "shells" and soapstone.
590	"	Soapstone and green serpentine.
670	"	Slate and soapstone.
680	"	Green serpentine, soapstone.
835	"	Slate and serpentine.
1109	"	Hard black slate and serpentine.
1187	"	Black "shells."
1560	"	

The rock is strikingly similar to that described by the Canadian driller. He found serpentine at 180 feet, in this well it first occurs at 166 feet. Furthermore in another well (No. 2) 45 feet N.E., serpentine was found at 183 feet. Likewise the black "shells" so often mentioned must be the black quartz referred to. Well No. 2 was carried only to 700 feet. Two gallons of naphtha were obtained at 580 feet but no more. The well described above gave a little gas at 467 feet, half a pint of naphtha at 700 feet, but no more till 1560 feet was reached.

Much water is obtained with the naphtha, the relative proportions being (average of 17 drawings).

Oil	72·5%	by volume.
Water	27·5%	

The oil figure includes a substance which the driller spoke of as "paraffin," and which will be referred to later as "emulsion."

The naphtha was of a very pale yellow color, and deposited on long standing, a slight, light brown sediment. It had:

Specific gravity, Westphal ..... 15·6° 0·732
N_D25° .... 1·4092

It gave a fire test below 0°.

An Engler distillation gave:

TABLE I.

Engler Distillation, Cuban Oil.

Temperature	% Wt.	Sp. gr. 15·6°	Sp. gr. 20°/20°	N_D25°
–75°	3·5	....	....	1·3900
75°–100°	18·9	0·72	....	1·4002
100°–125°	51·3	0·739	0·7372	1·4094
125°–150°	18·4	0·75	0·7497	1·4166
150°–160°	1·2	....	....	1·4242
Residue	2·1	....	....	1·4492

By way of comparison, two naphtha distillates from California petroleum, and samples of 62° and 88° naphtha obtained in open market, were distilled.

Table II.

Engler Distillation of California Naphtha Distillate.

Marked "64·7°"

Sp. gr. Westphal .... 15·6° 0·722
$N_D25°$ .... 1·4062

Temperature	% Wt.	Sp. gr. 15·6°	$N_D25°$
-50°	1·5	....	1·3750
50°-75°	19·4	0·660	1·3814
75°-100°	23·2	0·716	1·3987
100°-125°	24·9	0·756	1·4139
125°-150°	9·8	0·774	1·4261
Residue	6·0	0·808	1·4480

Table III.

Engler Distillation of California Naphtha Distillate.

Marked "64·5°"

Sp. gr. Westphal .... 15·6° 0·732
$N_D25°$ .... 1·4141

Temperature	% Wt.	Sp. gr. 15·6°	$N_D25°$
-50°	0·5	....	1·3752
50°-75°	13·5	0·678	1·3818
75°-100°	32·8	0·716	1·3987
100°-125°	24·6	0·740	1·4141
125°-150°	12·3	0·768	1·4270
Residue	5·9	0·810	1·4500

Table IV.

Engler Distillation of Commercial 88° Naphtha.

Sp. gr. Westphal .... 15·6° 0·651
$N_D25°$ .... 1·3695

Temperature	% Wt.	Sp. gr. 15·6°	$N_D25°$
-50°	47·7	0·609	1·3605
50°-75°	29·2	0·65	1·3756
75°-100°	6·8	0·70	1·3930
Residue	1·4	....	1·4061

Table V.

Engler Distillation of Commercial 62° Naphtha.

Sp. gr. Westphal .... 15·6° 0·732
$N_D25°$ .... 1·4106

Temperature	% Wt.	Sp. gr. 20°/20°	N_D25°
-50°	....	....	....
50°–75°	1·2	....	1·3830
75°–100°	20·0	0·7029	1·3956
100°–125°	51·9	0·7286	1·4061
125°–150°	24·6	0·7462	1·4168
Residue	9·2	....	1·4282

Practically all of the Cuban oil comes over between 75°–150°, half between 100°–125°. The California naphthas boil somewhat lower, a much larger part coming over 50°–100°. The 88° naphtha boils, of course, very much lower, but the 62° naphtha shows almost an identical composition by distillation, the fraction 125°–150° alone being larger.

Of the original oils, California 64·5°, 62°, and the Cuban oil have the same gravities, though the California index of refraction is higher than the other two.

A comparison of the different fractions is interesting. The first found in all is 50°–75°. The Cuban oil has the highest refractive index. The two California naphthas and the 66° are close together, while the 88° naphtha is lowest. In the portion 75°–100°, the Californias are nearly equal to the Cuban, while 62° and 88° are respectively lower. The gravities do not differ materially, but are in the same order from Cuban to 88°. Fraction 100°–125° shows a slight variation. 62° and 88° indices are equal and lowest, Cuban is next, with California highest. The gravities do not reveal anything, running Cal.–Cuba–Cal.–62°. The highest fraction, 125°–150°, gives similar constants for the Cuban and 62° naphthas, higher for the California.

It is hard to make a general summary of these comparisons. The Cuban oil boils identically with 62° naphtha, but higher than the California naphtha. The indices of refraction and specific gravities of its fractions are nearest those of 62° naphtha, but not as high as California naphtha.

The action of reagents on the original oils was as follows:

	Removed by 10% NaOH	33% H_2SO_4	Conc. H_2SO_4	Fuming H_2SO_4
Cuban oil.............	....	....	0·76%	1·8%
" fraction 145°–	....	....	0·2 %	2·5%
Cal. naphtha "64·5°"...	2·0%	2·9%	3·6 %	2·9%
62° naphtha...........	1·3%	....	1·3 %	2·5%

The refractive indices in each case were not materially changed.

The Cuban oil has practically no unsaturated compounds, even the 62° naphtha showing more action with acid, while the

California naphtha, besides 3 per cent nitrogen bases, has 6·5 per cent unsaturated hydrocarbons.

The California petroleums do not contain hydrocarbons of the series $C_n H_{2n+2}$.* The source of the 62° naphtha cannot be determined, but it in all probability contains both paraffins and naphthenes. The Cuban oil evidently is not composed entirely of naphthenes, which are characterized by higher gravity and index of refractions, nor yet of paraffins.

To further investigate its composition, a fractional distillation was made, with an 18-column Young dephlegmator condensing with an ice-salt mixture.

TABLE VI.

Fraction Distillation Cuban Oil.

Temperature	%	Specific gravity	N_D0°	N_D25°
-30°	1·6	0·589 0°/4 °	1·3706	....
30°–35°	0·5	....	1·3703	....
35°–50°	0·3	....	1·3772	...
50°–65°	1·0	....	1·3905	....
65°–75°	3·6	0·685	1·3975	1·3860
75°–85°	3·8	0·7266 20°/20°	1·4140	1·4020
85°–95°	6·8	0·7270	1·4155	1·4032
95°–105°	19·2	0·7308	1·4172	1·4061
105°–115°	7·2	0·7387	....	1·4112
115°–125°	17·2	0·7392	....	1·4121
Using a 4-bulb Hempel fractionator.				
125°–135°	6·8	0·7477	....	1·4162
135°–145°	7·2	0·7517	....	1·4181
Residue	8·1	0·7768	....	1·4302

Fraction—30°. Sp. gr. 0·589 (0°/4°), N_D0° 1·3706. n-Butane boils at 1°, tetramethylmethane at 10°; dimethylethylmethane at 30°, with sp. gr. 0·6385 (14°). This fraction must be composed of paraffin hydrocarbons as must also

Fraction 30°—35° N_D0° 1·3703
Fraction 35°—50° N_D0° 1·3772; calc. N_D25° 1·365

n-Pentane boils at 38° and has a refractive index of 1·3649; trimethylethylmethane boils at 49·6° and N_D25·5°=1·3602. This fraction also, by its index, is composed only of paraffin hydrocarbons.

Fraction 50°—65°. N_D0° 1·3905; calc. N_D25° 1·379. Di-iso-propyl boiling at 58° has N_D25°=1·3648. The index here is slightly high for pure paraffins.

Fraction 65°—75°. Sp. gr. 0·685 (0°/4°), N_D25°=1·3860.

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* Richardson, VI International Congress of Applied Chemistry, iv–a, 243.

n-Hexane boils at 71°,[*] sp. gr. 0·6630 (17°) N_D20° 1·3734; methylpentamethylene[†] boils at 71°, sp. gr. 0·7474 (21°/4°), N_D20° 1·4101. This fraction consists almost entirely of n-hexane with a small amount of methylpentamethylene.

Fraction 75°—85°. Sp. gr. 0·7266 (20°), N_D25° 1·4020. Here, also, we probably find n-hexane and methylpentamethylene and also hexamethylene boiling at 81°,[‡] sp. gr. 0·7771 (15°)[§] N_D18° 1·42897.[‖]

Fraction 85°—95°. Sp. gr. 0·7270, N_D25° 1·4032. Ethylisoamyl[¶] boils at 90·5°, sp. gr. 0·6819 (17·5); 1, 3, dimethylcyclopentane[**] boils at 91°, sp. gr. 0·7410 (24°/4°), N_D18° 1·4253. Evidently contains both paraffins and naphthenes.

Fraction 95°—105°. Sp. gr. 0·7308 (20°), N_D25° 1·4061. n-Heptane boils 98·4°,[††] sp. gr. 0·6886 (15°),[‡‡] N_D20° 1·3854;[§§] methylcyclohexane[‖‖] boils 103°, sp. gr. 0·7662 (18·5°/4°), N_D19° 1·4243.[¶¶] Paraffins and naphthenes both are present.

Fraction 105°—115°. Sp. gr. 0·7387 (20°), N_D25° 1·4112.

Fraction 115°—125°. Sp. gr. 0·7392 (20°), N_D25° 1·4121. n-Octane boils 125·5°,[***] sp. gr. 0·7020 (20°),[†††] N_D 1·3943;[‡‡‡] two unknown octanes described by Mabery and Hudson[§§§] boil at 119·5° and 124°—125°, and have gravities (20°) of 0·7243 and 0·7134; octonaphthene[‖‖‖] boils at 119°, sp. gr. 0·7503 (18°) N_D20° 1·4234;[¶¶¶] isooctonaphthene[****] boils at 124°, and has sp. gr. 0·7637 (17·5°). The percentage of naphthenes in each fraction seems to increase with the temperature. In this fraction, nearly equal amounts of paraffins and naphthenes are present.

Fraction 125°—135°. Sp. gr. 0·7477 (20°), N_D25° 1·4162. β—Nonane[††††] boils 129·5°, sp. gr. 0·725 (24·7°); nonanaphthene[‡‡‡‡] boils 135°—136°, sp. gr. 0·7667 (20°/0°). Here also is a mixture of the two classes of hydrocarbons.

Fraction 135°—145°. Sp. gr. 0·7517 (20°), N_D25° 1·4181. α—Nonane[§§§§] boils 135°—137° and has sp. gr. 0·742 (12·4°).

From these constants we can see that the lower boiling hydrocarbons are of the paraffin series while those coming over at higher temperatures contain increasing percentages of naphthenes, approximately equal amounts being finally found.

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[*] Engler and Routala, Ber. xlii, 4615.

[†] Engler and Routala, loc. cit.

[‡] Fortey, J. Chem. Soc., lxxiii, 932.

[§] Fortey, loc. cit.

[‖] Engler and Routala, loc. cit.

[¶] Schorlemer, Ann., cxxxvi, 259.

[**] Engler and Routala, loc. cit.

[††] Francis, Young, J. Chem. Soc., lxxiii, 921.

[‡‡] Thorpe, Ann., cxcviii, 364.

[§§] Engler and Routala, loc. cit.

[‖‖] Knoevenagel. Ann., ccxcvii, 159.

[¶¶] Zelinsky, Ber., xxviii, 1022.

[***] Thorpe, J. Chem. Soc., xxxvii, 217.

[†††] Engler and Routala, loc. cit.

[‡‡‡] Engler and Routala, loc. cit.

[§§§] Am. Chem. J., xix, 255.

[‖‖‖] Engler and Routala, loc. cit.

[¶¶¶] Knoevenagel, loc. cit.

[****] Engler and Routala, loc. cit.

[††††] Lemoine, Bull. Soc. Chem., Paris, xli, 164.

[‡‡‡‡] Konowalow, J. Russ. Chem. Ges., xix, 255.

[§§§§] Lemoine.

It has already been mentioned that with the naphtha, a substance was obtained which was described by the driller as paraffin. It was a grey substance, somewhat gelatinous, and similar in appearance to an oil emulsion. Its composition was found to be:

Oil	81%
Water	14%
Clay	5%

in the form of an emulsion.

The oil had a

Sp. gr. Westphal 15·6°	0·738
$N_D 25°$	1·4100

Distillation Engler.

Temperature	%	15°	Sp. gr. 20°/20°	N_D25°
–75°	0·4	----	----	1·4045
75°–100°	18·0	0·72	0·7217	1·4006
100°–125°	56·4	0·74	0·7372	1·4090
125°–150°	18·4	0·75	0·7500	1·4161
Residue	3·4	----	----	1·4499

This oil is practically identical with the clear naphtha, except for a slightly higher gravity. It was more deeply colored and had a larger amount of brown sediment.

Action with reagents. Oil from emulsion. Removed by

Soda	·6%
Concentrated acid	1·5%
Fuming acid	0·0%

The water had 2·31 per cent total solids.

The clay, which was gray, lost 15·7 per cent on ignition, the iron being oxidized. It was submitted to the Office of Public Roads, Washington, D. C., and an examination by Dr. Lord showed that the indurated material consisted essentially of highly decomposed fragments of a ferruginous rhyolitic glass and rounded grains of bitumen cemented together by chalcedonic silica and an indefinite hydrated silicate. The clay is composed of the secondary products resulting from the decomposition of the rhyolite, with some bitumen grains and fragments of undecomposed glass.

The emulsion is of the greatest interest.

Gilpin and Cram have shown* that when petroleum is allowed to rise in a tube packed with fuller's earth, a fractionation results, the fraction at the top of the tube has a lighter gravity than that at the bottom, and that the saturated hydrocarbons come to the top while the unsaturated are lower. Also when water is added to the fuller's earth containing the petroleum, the oil is displaced, but about one-third of the oil remains in the earth.

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* Am. Chem. J., xl, 495. This property was first pointed out by Day, Proc. Am. Philos. Soc., xxxvi, 154.

Day and Gilpin* have carried this work further and have obtained similar results with clay. They have pointed out its application to the accumulation of petroleum in different places.

We have in this Cuban oil an exact confirmation of these experiments by nature. It will be remembered that from the oil well there was obtained naphtha, water and emulsion. The history of this naphtha may be very briefly told. At some depth, considerably below 1500 feet, a crude petroleum filtered up through this rhyolitic clay,† the upper part of the clay stratum by fractionation containing the lightest naphtha. Saline waters then came in contact with this upper clay layer, displacing two-thirds of the oil contained in it and forming with it the emulsion. In Trinidad asphalt, as shown by one of us,‡ we have an exactly similar case of a permanent emulsion of bitumen, water and mineral matter.

To summarize briefly, we have examined a naturally occurring white naphtha from the province of Santa Clara, Cuba. It occurs at a depth of 1560 feet in black quartz and green serpentine with water and an emulsion of oil, water and rhyolitic clay. It contains practically no unsaturated hydrocarbons, but a mixture of paraffins and naphthenes. Over 50 per cent distills between 100°–125°, and very little above 150°. It was undoubtedly formed by the upward filtration of a heavy petroleum through the clay stratum, similar to the fuller's earth filtrations of Gilpin and Cram, and the light naphtha in the upper part of the stratum was afterwards partly liberated by saline waters, the oil remaining in the clay forming with water the emulsion.

Our thanks are due to Mr. L. W. Page of the Office of Public Roads for the examination of the clay, and to the Cuban American Sugar Company, the owners, for permission to publish these results.

New York Testing Laboratory,
January 31, 1910.

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* Ind. Eng. Chem., i, 449.

† It may be stated that the drillers are confident of finding a heavy petroleum at greater depths.

‡ Richardson, Proc. Am. Soc. Test. Mat., vi, 509.

ART. XLI.—*Intrusive Granites and Associated Metamorphic Sediments in Southwestern Rhode Island;* by G. F. LOUGHLIN.

CONTENTS.

- Introduction.
  - Bibliography.
- Résumé of evidence in S. E. Connecticut.
- Evidence at Westerly and Niantic, R. I.
- Reconnaissance eastward to the Kingstown area.
- The Kingstown area.
  - Granite.
  - Time of intrusion.
  - The Kingstown sediments.
  - Granite pebbles.
  - Derivation and correlation of the Kingstown sediments.
- Summary.

INTRODUCTION.

Studies in southeastern Connecticut and southwestern Rhode Island have convinced the writer that all the granites in this area are parts of one composite batholith, and that this batholith is not of pre-Cambrian age, but is intrusive into rocks that have been mapped as Carboniferous. A detailed report on the southeastern Connecticut portion was completed about two years ago, and is awaiting publication by the United States Geological Survey.*

The present paper expresses the results of reconnaissance work from the Connecticut–Rhode Island boundary eastward to the vicinity of Narragansett Basin and of more detailed study along the western border of the Basin—here designated the Kingstown area.

Bibliography.—The granites of the area studied have been mentioned in a few publications, but their ages and structural relations have seldom received close attention, especially at critical points. C. T. Jackson, in 1840, mapped the granite as "Primary"† and the sediments of the Narragansett Basin as "transition graywackes" derived from the Primary. In 1899, Shaler, Woodworth, and Foerste published "The Geology of the Narragansett Basin, R. I."‡ Shaler and Foerste, who worked in the area under discussion, gave little attention to the granites bordering the Basin. They regarded them as Algonkian and distinct from the pegmatite dikes that cut the Carboniferous strata of the Basin. The latest geological map of North America§ represents the granite as pre-Cambrian.

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* Contributions to Geology of Eastern Connecticut.

† Geol. and Agricult. Surv. of the State of R. I., 1840.

‡ U. S. Geol. Surv., Mon. XXXIII, 1899.

§ Bailey Willis, Geol. Map of No. America, 1906.

B. K. Emerson and J. H. Perry* in 1907 described and mapped the formations along the western border of the Narragansett Basin. The southern end of their area overlaps the northeast corner of the area here discussed, but no contacts are there exposed. They also mapped the granite as pre-Cambrian (fig. 1 of this paper).

Résumé of Evidence in S. E. Connecticut.

As the writer's work here described has been essentially a continuation of his studies in southeastern Connecticut, a summarized statement of the character and relations of the granite and adjacent metamorphic sediments in that area is here given to serve as a basis for correlation.† A portion, also, of the map is copied (fig. 1, west of long. 71° 45′ and north of lat. 41° 25′).

The metamorphic sedimentaries shown in the map are a quartzite (Plainfield quartz-schist) and a more extensive quartz-biotite-schist, more or less feldspathic (part of the Putnam gneiss series). These, and closely related metamorphics not shown in the map are characterized by the general predominance of plagioclase wherever feldspar is present. The composition of the plagioclase ranges from Ab_3An_1 to Ab_1An_1. They are possibly of Carboniferous age.

The granite—Sterling granite series—mostly of pink color and gneissoid structure, includes three varieties: normal biotite-granite, porphyritic biotite-granite, and alaskite. The alaskite is known to cut the other two varieties, but all gradations in composition and texture appear. All the varieties are intrusive into the sedimentary series. Pegmatite and aplite, in sheets and dikes, cut the granite series, and are abundant in the metamorphic sediments. The granite series is characterized by a well-developed microline, in some cases microperthitic, white oligoclase, or albite, and some quartz.

The relation of the micro-textures of the granites to regional metamorphism has been treated at some length in the original paper, with the conclusion that the normal and porphyritic types were intruded and crystallized while the disturbing forces were most active, and that the alaskite became solid during the waning stage of regional movement. This relation, if the sedimentary series includes Carboniferous rocks, correlates the time of metamorphism and intrusion with that of the Appalachian Revolution. The question of age will be furthur considered towards the end of this paper.

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* The Green Schists and Associated Granites and Porphyries of Rhode Island, U. S. G. S. Bull. 311, 1907.

† By permission of the Director of the U. S. Geol. Survey.

Evidence at Westerly and Niantic, R. I.

The writer during the past six years has made several visits to the Westerly, R. I., granite quarry district along the southern part of the Connecticut boundary, and one visit to the neighboring and similar district of Niantic, R. I. (fig. 1) He finds at these places the above summarized evidence duplicated and supplemented by a later intrusion—that of the Westerly granite. Metamorphic sediments here appear only as isolated inclusions in granite. Both the sediments and the Sterling granite series are cut by dikes of the fine-grained Westerly granite (quartz-monzonite according to Dale).* The latter rock has the same mineralogic characters as the Sterling granite, differing only in containing a higher percentage of plagioclase. Its contact phase and apophyses are medium-grained to pegmatitic, and cannot be distinguished in the specimen from the Sterling granite series. The contacts of the Westerly with the Sterling granite are sharp, but the close petrographic resemblance between the two rocks and the absence of any evidence indicative of widely different age favor the interpretation that the Westerly granite is not a type independent of the Sterling granite series, but the latest exposed phase of the same batholith.

Reconnaissance Eastward to the Kingstown Area.

Two reconnaissance traverses have been made across southwestern Rhode Island, one extending from the southeastern Connecticut area eastward to Wickford Junction, the other from Hope Valley southward to Niantic and thence eastward, in a zigzag course, to Wakefield (fig. 1). The outcrops visited are plotted on the map. Those along the first, or northern, traverse are identical in character with the normal gneissoid Sterling granite, save one outcrop of the porphyritic type a mile west of Millville. The normal type is disintegrated to a considerable extent, a characteristic feature in parts of southeastern Connecticut, and some outcrops are completely reduced to a coarsely granular soil to a depth of six feet or more.

Short veins of pegmatite and pegmatitic quartz, from less than an inch to one foot in width, are commonly present, most of them cutting across the schistosity of the granite. One small dike of fine-grained granite, similar to the Westerly type, was noted on the southward sloping ridge 1⅛ miles east of Pine Hill. No inclusions of the metamorphic sediments were found.

A glance at the map will show that no outcrops were found along the eastern three miles of the traverse; but over 99 per cent of the abundant bowlders in these three miles, and in fact along the whole traverse, are of the normal gneissoid Sterling granite, and it is the writer's experience that the majority of bowlders in southern New England are of strictly local origin. The granite therefore is believed to be continuous from the Connecticut boundary to the edge of the Narragansett Basin, 1½ miles west of Wickford Junction, but the relations there between the granite and the rocks of the Basin are concealed by drift.

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* Dale, T. N., The Chief Commercial Granites of Mass., N. H. and R. I. Bull., U. S. G. S., No. 354, 1908, pp. 190 et seq. The reader is referred to this Bulletin for structural and petrographic details.

The eastern part of this traverse overlaps a small part of the area mapped by Emerson and Perry as a southward continuation of the pre-Cambrian Northbridge gneiss of Massachusetts. The thorough concealment of all contact relations renders it impossible at this point to choose between the conclusion of the authors cited and that of the writer. Evidence supporting the writer's views will be presented in the description of the Kingstown area.

Evidence along the southern traverse is not quite so inconclusive as that just presented. The granite outcrops are all of the Sterling types, chiefly the normal and to some extent the porphyritic. Two small dikes of the Westerly type were noted; one a mile south of Plainfield, the other on the summit of Shumunkanug Hill. No outcrops were found along the eastern six miles of the traverse, but here again practically all the bowlders are of the Sterling granite.

Exposed inclusions of the metamorphic sediments are very scarce and only one deserves mention. This one lies in the road on the hill a mile west of Worden's Pond (see map, fig. 1). Its texture is pseudo-porphyritic with flattened, lens-shaped pebbles of quartz-schist, but the matrix is identical in color and texture with the quartz-biotite schist exposed in southeastern Connecticut and at Westerly. It is also similar to the most severely metamorphosed conglomerate in the Kingstown area. It is cut by a narrow pegmatite dike of the Sterling (or Westerly) type. This evidence though limited proves that the age relations found in Connecticut and at Westerly exist as far east as Worden's Pond.

The Kingstown Area.

The limits of the Kingstown area are shown in fig. 2. It includes the west boundary of the Narragansett Basin sediments from Hamilton southward, and has yielded decisive evidence for determining the relative ages of the rocks in question. The area was studied and mapped in detail by Messrs. Y. S. Bonillas and V. M. Frey under the writer's direction.* The

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* MS. thesis No. 340, 1908, Min. Dept. Mass. Inst. Tech., Boston, Mass.

FIG. 1.

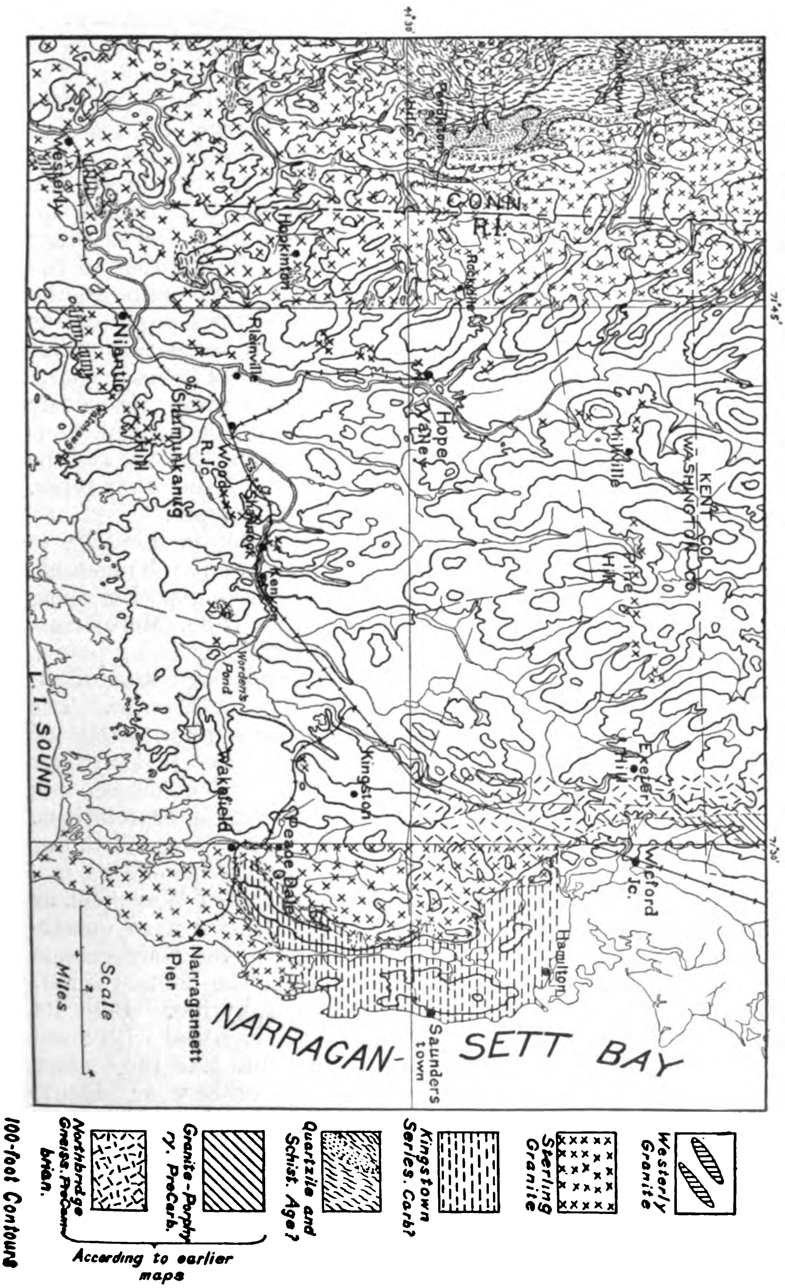

FIG. 1. Geologic map of S. W. Rhode Island and S. E. Connecticut. Detailed mapping is expressed only in the eastern and western portions of the area. Only outcrops seen by the writer are shown in the central portion, which is believed to consist essentially of the Sterling granite.

writer has not visited every outcrop in the area, but has studied the continuous exposures along the shore of the Bay, and all the exposed granite contacts, and has examined thin sections of the several rock types represented.

Granite.—The various granite exposures include types identical in texture, mineral composition, and structural relations with the several members of the Sterling series (including the Westerly granite). These types and their relations to one another are perfectly shown in the continuous granite ledge which extends along the shore of the Bay from Narragansett Pier for two miles southward. There is, in addition to the types previously mentioned, a pegmatitic muscovite granite which, as will be shown presently, is a contact phase of the Sterling batholith, and is transitional into those pegmatites which were previously interpreted as post-Carboniferous.* Muscovite variations are present in the areas previously described, but only in the Kingstown area are they conspicuous and important. The feldspars of the muscovite granite are the same in character and composition as those of the other types. Schist inclusions are found in all the granite types.

Normal and porphyritic Sterling granite, moderately to highly gneissoid, are the prevailing types in the Kingstown area. They comprise the body of the two-mile exposure along the shore, and are exposed to the north on Rose, McSparren, and Hammond Hills. Exposures are few at intervening points, but are of the same types of granite. Small pegmatite dikes, more or less muscovitic, are of common occurrence. The northern part of this area also overlaps the southern limits of the area previously mapped as pre-Cambrian (see p. 448); but here again, owing to the general lack of local evidence, it is impossible to choose between the differing interpretations. Weathered schist inclusions are found on McSparren Hill, but the presence of these alone is not convincing evidence.

Definite evidence, however, is afforded east of Wakefield, at the bend of Indian Run, in an exposed contact with quartz-biotite schist, the metamorphic sediments of the Narragansett Basin. The granite a short distance from the contact is red, distinctly gneissoid, and irregularly porphyritic. Both its megascopic and microscopic characters are identical with those of the Sterling granite types of Connecticut. As the contact is approached, the gneissoid character is obscure or absent, and pegmatitic segregations are numerous. Distinct dikes of pegmatite are also present, cutting the granite. The adjacent schist is penetrated by many pegmatitic apophyses, most of which follow the foliation plains.

A mile eastward, along the southeast slope of Tower Hill,

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* U. S. G. S. Mon. XXXIII, p. 377.

FIG. 2.

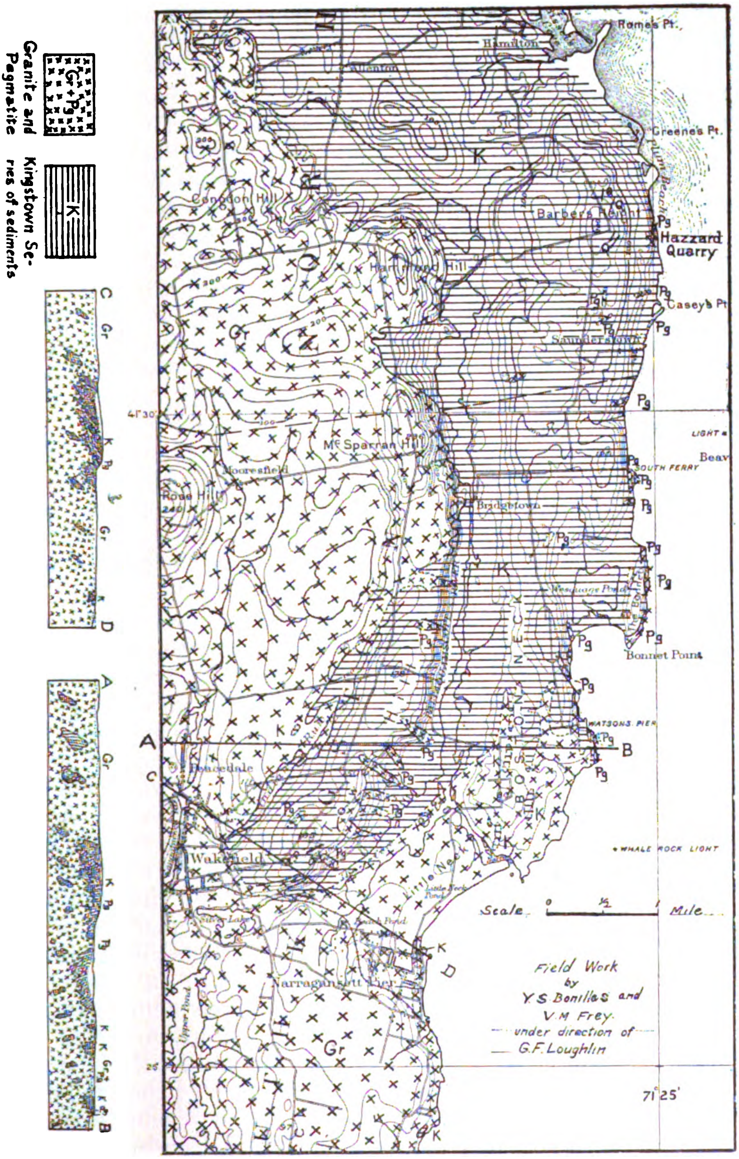

FIG. 2. Detailed geologic map and sections of parts of North and South Kingstown, R. I., along the western border of the Narragansett Basin. Boundaries actually exposed or definitely located are represented by solid lines; indefinite boundaries by dotted lines. The dotted lines in the sections indicate the unexposed surfaces of bed rock.

are excellent exposures of granite apophyses following and cutting across the foliation of the schist. The apophyses are medium-grained to pegmatitic, slightly to highly muscovitic, and of red to white color. The white color is more pronounced in the more highly muscovitic rock. The pegmatitic and muscovitic characters are best developed in the large dikes (fig. 2), which cut approximately at right angles to the foliation of the schists. These dikes, or large apophyses, are exposed at intervals along Tower Hill towards Bridgetown. Excavations in a graphitic bed of the schist, between one and two miles south of Bridgetown, have exposed pegmatite dikes and associated quartz veins. The graphitic rock is also cut by small, branching, fibrous veins composed chiefly of sillimanite, quartz, and muscovite. These veins are believed to be genetically associated with the pegmatite, but no careful study has yet been given them in connection with the problem under discussion.

Similar, and even more convincing, evidence is found along the shore of the Bay from Little Neck northward to Hazzard's quarry. The muscovitic granite with schist inclusions is the prevailing rock on Little and Boston Necks. It is increasingly muscovitic and pegmatitic as the contact with the schists is approached. At Watson's Pier schist, cut by many large dikes of the granite and pegmatite, is the prevailing rock. Large pegmatite dikes are numerous along the coast as far as the north end of the Bonnet, and outcrop at intervals as far north as Saunderstown. From this point northward, pegmatite dikes are scarce, and the northernmost exposure seen is at Hazard's quarry. Here is a small dike consisting chiefly of quartz with a little feldspar and practically no mica. A few quartz veins with rare feldspar crystals, exposed near the summit of Barber's Heights, are the northernmost pegmatitic exposures found. The evidence in the Kingstown area, therefore, appears conclusive that the granites bordering the metamorphosed Narragansett Basin sediments are members of the Sterling batholith and are intrusive into the schists. Petrographic study proves that the pegmatite dikes on Tower Hill and along the shore of the Bay are not independent intrusions, but apophyses from Sterling batholith, tending to grade into quartz veins as the distance from the batholith increases. Evidence in the whole area studied has proved that the granites of southwest Rhode Island, south of the Washington Co.–Kent Co. boundary (fig. 1) are not of pre-Cambrian age as previously supposed, but belong to the Sterling batholith, the youngest formation (including the Westerly granite dikes) of the area.

Time of Intrusion.—The details of metamorphism in the

Kingstown area have not been exhaustively studied, but it is very evident, from the field work done, that vertical dips and the most complete recrystallization of the sediments are found where granitic intrusions are most abundant. There seems, then, no reason for doubting that in the Kingstown area, as well as in southeastern Connecticut, the granite intrusion accompanied metamorphism and folding. As the Kingstown sediments have been determined to be of Carboniferous age,* the time of granite intrusion and folding may be correlated with the Appalachian Revolution.

The Kingstown Sediments.—As the Kingstown sediments have heretofore been regarded as resting uncomformably upon the granite, a study of their composition is necessary for a complete solution of the problem here considered, and as a check on the conclusions already reached. Detailed descriptions of outcrops have been made by Foerste,† and only petrographic evidence is considered here.

The sediments comprise chiefly an alternating series of light to dark gray arkose, conglomerate and phyllite beds, with at least one highly graphitic bed. Metamorphism effects are everywhere distinct, varying from moderate around Hamilton, the northernmost point studied, to extreme in close proximity to granite contacts. In the latter case traces of clastic structure are nearly, or quite, obliterated, and the rocks are typical gray gneisses and schists, penetrated by the reddish granite.

The pebbles of the less metamorphosed conglomerate comprise quartzite, quartz-sericite schist, black very fine-grained slaty schist, vein-quartz, felsite-porphyry, a fine even-grained granite. The granite pebbles, which do not resemble the Sterling or Westerly granite, will be separately described below. In the highly metamorphosed conglomerate, the pebbles appear as flattened lenses and even linear streaks. Only the less severely mashed are clearly recognizable. The arkose and the matrix of conglomerate consist of quartz, feldspar, biotite, and muscovite in varying amounts. The most metamorphosed exposures present the same general megascopic characters and variations as the quartz-biotite schist of southeastern Connecticut. Thin sections prove the feldspars to be mostly plagioclase with a few of poorly defined microperthite and, possibly, of orthoclase. Not a feldspar grain was noted with the well-developed microcline twinning so characteristic of the feldspar in the Sterling and Westerly granite, save in the one instance, 1¼ miles south of Narragansett Pier, of a schist inclusion which is thoroughly injected with dikelets and stringers from the granite.

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* Mon. XXXIII, U. S. G. S., plate xxxi.

† Op. cit., pp. 215 et seq.

Granite Pebbles.—The granite pebbles in the conglomerate are light gray to pink, fine even-grained to sub-porphyritic, and consist of finely intergrown quartz and feldspar with a little biotite and muscovite. Three thin sections were studied; one of a pebble from an outcrop 1½ miles west of Wickford Junction (fig. 1), one from an outcrop ¼ mile southeast of Hamilton, and one from a bowlder south of McSparren Hill. The three thin sections present the same characters. The texture is conspicuously micrographic. The primary minerals are plagioclase and microperthite in about equal amounts, quartz, biotite, and the usual minor accessories; the chief secondary minerals are muscovite, replacing feldspars, and chlorite replacing biotite. The microperthite is the same type as that noted in the arkose and conglomerate matrix. The plagioclase mostly corresponds to oligoclase-andesine, though some grains appear more basic. These characters suffice to point out the decided lack of resemblance to the Sterling granite.

Derivation and Correlation of the Kingstown Sediments.—The composition of the Kingstown sediments thus verifies the conclusions already stated, and no evidence whatever remains to indicate that the Sterling granite is not the younger rock. The Kingstown sediments were derived from a series of quartzites and black slaty schists, felsite-porphyry, and igneous rocks containing considerable plagioclase. The plagioclase may come wholly or in part from the fine-grained granite and possibly in part from more basic igneous rocks, no pebbles of which have yet been found. None of these rocks are found within the area studied, but they may be represented in the Cambrian formations and the granite-porphyries to the north.*

The general similarity in mineral composition between the Kingstown sediments and the quartz-biotite schists of the southeastern Connecticut and the Westerly–Niantic, R. I., districts favors the correlation of these rocks as parts of one extensive formation. Fossil evidence in the areas studied is wholly lacking, but structural and petrographic evidence favors this provisional conclusion.

Summary.

The principal conclusions reached in this paper are as follows:

1. The Westerly granite is closely related to the Sterling granite in general character and mineral composition, and is considered the latest exposed phase of the Sterling batholith.

2. The Sterling granite batholith is continuous from eastern Connecticut to Narragansett Bay, R. I., and includes granite formerly thought to be pre-Cambrian. There are no

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* Emerson and Perry, op. cit., pl. 1.

pre-Cambrian rocks in Rhode Island south of the Washington Co.–Kent Co. boundary.

3. The Sterling granite batholith is intrusive into all the sediments with which it is in contact, including the Kingstown sediments of the Narragansett Basin, and its intrusion accompanied metamorphism and folding.

4. Since the Kingstown sediments are said to be of Carboniferous age, the time of the granite intrusion, metamorphism and folding may be correlated with that of the Appalachian Revolution.

5. The Kingstown series were derived principally from metamorphic rocks of possible Cambrian age, from felsite-porphyry, fine-grained micrographic granite, and possibly more basic igneous rocks.

6. In the absence of fossil evidence, structural and petrographic data favor provisional correlation of the Kingstown sediments with the quartz-biotite schists found in southeastern Connecticut and at Westerly and Niantic, R. I.

Massachusetts Institute of Technology.

SCIENTIFIC INTELLIGENCE.

I. Chemistry

1. *Metallic Zirconium.*—Weiss and Neumann have succeeded in preparing fused zirconium in a pure condition. The metal has been previously known only as an impure powder, or containing much carbon when fused. This difficult operation was performed, after many failures, by compressing the powder into pencils and passing an electric arc from the end of one pencil to another, either in a vacuum furnace containing hydrogen under very low pressure, or in the same apparatus containing an atmosphere of nitrogen or ammonia. The upper pencil, forming the positive pole, was fused and the metal dropped upon the lower electrode, forming a stalagmite-like mass which was sometimes 3 or 4^{mm} in diameter and 2 or 3^{cc} high. The light produced at the melting point was so intense that the eyes had to be protected by very dark glasses when the operation was watched through the window of the apparatus. The fused zirconium was somewhat tarnished, but the fracture was white and metallic like cast iron. It was slightly harder than quartz, and decidedly less hard than Moissan's product containing carbon. It was very brittle, with a specific gravity of 6·400. The specific heat was found to be 0·0804, a value considerably higher than any previous determi-

nation and giving an abnormal atomic heat, 7·316. It burns in air, and the average heat of combustion was found to be 1958·7 cal.—*Zeitschr. anorgan. Chem.*, lxv, 248. H. L. W.

2. *The Gas-volumetric Determination of Hydrogen.*—Heretofore no liquid reagent has been known for the absorption of hydrogen in gas analysis, but **Paal** and **Hartmann** have found such a reagent which can be used with accuracy in technical gas analysis, and which can be employed also for removing hydrogen from certain gases in preparative work. The reagent is a solution of colloidal palladium and sodium picrate. The metallic palladium first absorbs the hydrogen, then immediately acts as a catalytic agent by transferring the hydrogen to the sodium picrate and reducing the latter to triamidophenol:

$$C_6H_2(NO_2)_3OH + 18H = C_6H_2(NH_2)_3OH + 6H_2O.$$

The absorption requires a little time, depending upon the amount of palladium present in the liquid. Experiments with various mixtures showed that accurate results could be obtained by the method. Since the reagent effects the combination of hydrogen with oxygen if both are present, and as it also causes the combination of hydrogen with unsaturated hydrocarbons, the procedure required in ordinary gas analysis is the application of the reagent after the carbon dioxide, unsaturated hydrocarbons, oxygen and carbon monoxide have been removed by the usual methods.—*Berichte*, xliv, 243. H. L. W.

3. *Theoretical Principles of the Methods of Analytical Chemistry;* by M. G. **Chesneau**, translated by A. T. Lincoln and D. H. Carnahan. 8vo, pp. 184. New York, 1910 (The Macmillan Company).—In its general object this book is similar to Ostwald's well-known work on the subject, but instead of advocating the theory of ions, the present author employs what he calls a calorimetric method for explaining certain reactions. He admits that Ostwald's plan is certainly more attractive *à priori* than the calorimetric method, but he objects to the electrolytic theory, and gives an extensive discussion of the objections, based chiefly on the work of Kahlenberg. Teachers of analytical chemistry, as well as advanced students, will doubtless find much that is suggestive and interesting in the book, particularly if they prefer the mathematical form of discussion. H. L. W.

4. *Analyse Volumétrique;* par **Louis Duparc** et **Mario Basadonna**. 8vo, pp. 170. Geneva and Paris, 1910 (Kündig, Geneva; Felix Alcan, Paris).—This theoretical and practical manual of volumetric analysis has been prepared particularly for the purposes of laboratory instruction, but it is intended to be useful also to the practical analyst. It contains concise and clear descriptions of many of the best known and most frequently employed methods, including a number of special technical processes. Although it is not an exhaustive treatise on volumetric analysis, it will be found useful and suggestive in regard to some of the methods described. It has the fault of many French books in

lacking an alphabetical index, and since the subject matter is arranged according to general methods, and not according to the elements to be determined, it is not a convenient book for reference. H. L. W.

5. *Solid Bitumens*, by S. F. PECKHAM. 8vo, pp. 317. New York and Chicago, 1909 (The Myron C. Clark Publishing Co.).—This book is a treatise on the natural history, chemistry, physical properties, and technology of natural bitumens or asphalts. The author's extensive personal experience has been of much service in the preparation of the work, and much material from other sources is included. The uses of the solid forms of bitumen in the construction of pavements are very thoroughly discussed, and there is an interesting chapter on the oiled roads and streets of the Pacific Coast. H. L. W.

II. GEOLOGY.

1. *Iowa Geological Survey;* SAMUEL CALVIN, State Geologist; JAMES H. LEES, Assistant State Geologist. Vol. XIX, Annual Report for 1908, with accompanying papers. Pp. xiii and 779, ills. 117.—The original coal supply of Iowa is estimated at 29,160,000,000 tons; 141,608,792 tons have been mined up to and including 1908, which indicates that at the present rate of production the Iowa supply will last for 2550 years. The importance of the coal industry in Iowa justifies the publication of a number of papers dealing especially with this subject.

The first report by Henry Hinds on "The Coal Deposits of Iowa" (pp. 25–391) gives detailed descriptions of the geological relations, mode of occurrence of the Iowa coals and the present state of development of the coal industry for each township and district in the state. The Fuel Value of Iowa coal is discussed by Frank A. Wilder (pp. 401–497) and includes analyses by James H. Lees and A. W. Hixson, in which are given the results of the fuel tests at the plant established at St. Louis by the United States Geological Survey. The History of Coal Mining in Iowa by James H. Lees (pp. 521–597) is an interesting account of the successes and failures in coal mining from 1840 to 1908.

The chapter on the Carboniferous Section of Southwestern Iowa by George L. Smith (pp. 605–657) deals largely with the stratigraphy of the Missouri stage, and in this same report S. W. Beyer discusses the origin, distribution and commercial value of peat deposits in Iowa (pp. 693–725), and L. H. Pammell describes the flora of the northern Iowa peat bogs (pp. 739–776).

H. E. G.

2. *West Virginia Geological Survey;* I. C. WHITE, State Geologist. County Reports and Maps, 1909. Marshal, Wetzel and Tyler Counties, by RAY V. HENNEN, Assistant Geologist. Pp. xvi and 654, maps 3, plates xii, figures 3.—This second vol-

ume of the series dealing with individual counties has been prepared in accordance with the plan announced some years ago of furnishing reports dealing with various parts of the state, the plan being to include in one volume all the important geological matter pertaining to a given section.

From an economic standpoint, little criticism can be made of these reports since they discuss not only coal, gas, oil, building stone and clay, but also soils ; but as general reading books dealing with the geology of the section, they are not so satisfactory. It is a legitimate part of the work of a State Survey to publish the results of geologic research in a form which may be of use to schools and to the average intelligent man. The publications of the Wisconsin, the Illinois and the Connecticut Surveys indicate how this may be done.

The maps published with this volume are especially good, and the idea of combining the county maps into one map for the whole district is to be commended. H. E. G.

3. *New Zealand Geological Survey ;* J. M. Bell, Director. Bulletin No. 8 (New Series). The Geology of the Whangaroa Subdivision, Hokianga Division, by J. M. Bell and E. DeC. Clarke. Pp. v and 107, illustrations xvii, maps 8, geological sections 4.—Little geological work has previously been done in the area covered by this report, the northern edge of Auckland Island, although this part of New Zealand contained one of the earliest settlements and is widely known as a producer of kauri gum, which next to gold has contributed most to New Zealand revenues.

The rocks of this area include pre-Cretaceous, argillites, quartzites, and igneous rock; late Mesozoic and early Tertiary, the Kaeo series of sedimentaries ; Miocene, the Wairakau breccias, dikes and flows ; Miocene or post-Miocene, Kerikeri flows and underlying sediments ; post-Miocene lake beds, acid and basic volcanics. Since the deposition of the Wairakau series tectonic movements include little folding but extensive faulting. The surface as a whole is a faulted tableland deeply dissected and with volcanic cones rising above the level. The shore line is that of a typical depressed land surface. There are evidences of baseleveling on the surface of the Kaeo rock and renewed peneplanation occurred between Wairakau times and the extrusion of the Kerikeri volcanics. Rock benches are developed along the shore line, but they are believed not to represent planes of marine erosion, but rather to be due to the coöperation of subaërial weathering and marine transport. The freshwater lakes occupy basins due to damming by lava flows or explosion craters.

Chapters 4 and 5 of this report (pp. 41–79) are devoted to detailed descriptions of the stratified rocks with their fossils and the igneous rocks, including a number of analyses. In the chapter on economic geology (pp. 80–98), an interesting account is given of the occurrence of mercury, which seems to be directly associated with hot springs, as in the case of certain Nevada and California deposits, discussed by G. F. Becker. H. E. G.

4. *Certain Jurassic (Lias-Oolite) Strata of South Dorset; and their Correlation; Certain Jurassic ("Inferior Oolite") Species of Ammonites and Brachiopoda;* by S. S. BUCKMAN. Quart. Jour. Geol. Soc., London, lxvi, No. 261, February 1910, pp. 52–108, pls. ix–xii.—The author describes here in detail certain strata of the Jurassic of the Dorset coast and compares them with similar strata inland.

American geologists often doubt the ability of paleontologists to make correlations of zones having thicknesses from 10 to 50 feet, but Buckman here makes correlations of zones but a few inches in thickness! He states:

"The Inferior Oolite rocks are so remarkably prolific in species of Mollusca and Molluscoids—there is so great a number of species yet awaiting description—that there seems to be an idea among those who have not studied the rocks in the field, that they receive a kind of preferential treatment in this respect. Another explanation may be suggested—that our judgment as to the time occupied in the forming of the so-called 'Inferior Oolite' strata is warped owing to their tenuity—that they represent a time during which destruction of strata was particularly active, therefore the remaining deposits are only the fragmentary representatives of a whole.

"This is particularly the case in Dorset. A schoolboy once defined a net as a series of holes strung together, and the Dorset Inferior Oolite might be defined as a series of gaps united by thin bands of deposit. And one reason for the prolificness of the deposits is that the amount of deposit can be no indication of the amount of time, as shown by the changes in successive faunas; and also that the deposits are so local—the deposits of one place correspond to the gaps of another. Therefore many localities have to be placed together to produce the full tale of the Inferior Oolite. The very local distribution of Inferior Oolite species often means that strata of particular dates have only been preserved in a few favoured localities.

"The beds of the 'Inferior Oolite,' in a restricted sense, have now been divided as deposits of about twenty-two successive dates or hemeræ. The total for the whole of the Jurassic would not be more than about eighty-five, or perhaps, on an extended scale, a hundred hemeræ. Therefore, according to this reckoning, the few feet of Inferior Oolite represent from about a quarter to a fifth of the total time occupied in the deposition of the entire Jurassic System.

"One can hardly view the few feet of Inferior Oolite limestone at Burton Bradstock, about 15 to 20 feet say, and imagine that it represents an interval of time equal to a quarter or a fifth of the whole Jurassic Period—a time during which thousands of feet of strata were laid down. But this is because we do not allow sufficiently for the gaps.

"If anything like this supposition be correct, then the Inferior Oolite prolificness is understandable; it should represent in species as many as would form from a quarter to a fifth of the total for the Jurassic System. At that rate, its tale is nothing like complete yet; which all workers in its rocks know to be the case." (90–91.)

"The strata described are classified according to what may be called the multizonal or polyhemeral system—in the main, according to the scheme introduced for these strata in 1893 (Quart. Jour. Geol. Soc., vol. xlix, p. 481); but further divisions due to other investigators and to myself are dealt with.

"The strata described are arranged among thirty-six zonal (hemeral) divisions—a greater number of divisions than Oppel used in 1856 for all the Jurassic rocks, of which these beds form but a small part.

"The Upper Lias part of the Junction Bed of Down Cliffs, Chideock (Lower or pre-*striatulus* Toarcian), is a very condensed, imperfect epitome in 20 inches of about 180 feet of strata on the Yorkshire coast, and of very much more when allowing for gaps.

"Between the *bifrons* layer and the *striatulus* layer of the Junction Bed there is occasionally a 2-inch layer which is all that represents some 250 feet of deposit in the Cotteswolds—so that about two feet of Junction Bed was formed while a thickness of some 550 feet was being deposited elsewhere." (89.)

"The President (Prof. Sollas) congratulated the author on the very interesting manner in which he had presented a highly technical subject. The correlation of thin seams with thick deposits was a matter of great importance, and called to mind Suess's remarks on the partings in the Trias. It might afford some hints as to the order of magnitude of the scale of time. If we assumed that one foot of sediment might accumulate in a century, in an area of maximum deposition, then in the case of the seam two inches thick which was represented by 250 feet in the Cotteswolds, the rate of formation would be less probably than one foot in 150,000 years.

"The Author, in reply, remarked that Jurassic zones were by no means the result of local observation only; they had been followed widely, even the new ones; the thinness of zones was no test of their importance or otherwise, being often only a local accident of alternating deposition and denudation. The net increase of deposit must have been much less than one foot in a century, as this seemed too rapid for the faunal changes involved." (109, 110.) C. S.

5. *Palæontologia Universalis*, ser. II, fasc. IV, 1910.—This fasciculus contains 71 sheets redescribing 35 species of fossil echinoderma and mollusca, and completes the second series having 169 sheets. The entire set may be had for $8.00 of G. E. Stechert, 9 East 16th St., New York City. C. S.

6. *Geologic Atlas of the United States. Folio 169, Watkins Glen-Catatonk, New York, 1909;* by H. S. WILLIAMS, R. S. TARR, and E. M. KINDLE.—The topography and the Quaternary deposits are described in detail by Tarr, the Upper Devonian

stratigraphy by Williams and the igneous rocks and historical geology by Kindle. The interfingering of the western Portage faunas into the eastern Hamilton-Chemung biotas is clearly described and is of much interest to stratigraphers. C. S.

7. *Geology of the Auburn–Genoa Quadrangles;* by D. D. LUTHER. Bulletin 137 N. Y. State Museum, 1910, 36 pages and geologic map.—An excellent description of the areal geology of the region of Cayuga and Owasco lakes. The formations range from the upper part of the Silurian to the close of the Devonian. C. S.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The annual Spring meeting of the National Academy was held at Washington on April 19 to 21; some forty members were in attendance.

The following new members were elected: Douglas H. Campbell, Professor of Botany in Stanford University; John Dewey, Professor of Philosophy in Columbia University; Jacques Loeb, Professor of Physiology in the University of California; Forest R. Moulton, Professor of Mathematics in the University of Chicago; William A. Noyes, Professor of Chemistry in the University of Illinois; Thomas B. Osborne, Chemist of the Connecticut Agricultural Experiment Station; Charles Schuchert, Professor of Paleontology in Yale University. Professor Giovanni Schiaparelli, the astronomer, of Milan, Italy, was elected foreign associate.

The list of papers presented at the meeting is as follows:

E. C. PICKERING: The 16-inch Metcalf doublet.

GEORGE E. HALE: Solar magnetism. Some visual and photographic observations of Mars.

WILLIAM TRELEASE: The distribution of Agave in the West Indies.

JOHM M. COULTER: The vascular plate and cotyledons of Gymnosperms.

F. E. NIPHER: Some crucial experiments demonstrating the necessity of accepting the one-fluid theory in electricity.

W. J. HUMPHREYS: A probable indirect relation between solar disturbance and terrestrial temperatures.

E. A. HARRINGTON: Quantitative studies of tuning forks.

S. W. STRATTON: The Bureau of Standards.

ARTHUR L. DAY: The determination of temperature constants in mineral formations.

J. M. CRAFTS: A new form of gas thermometer and the boiling points of water and naphthalene.

H. N. MORSE: The temperature coefficient of osmotic pressure.

H. L. ABBOTT: Hydraulics of the Chagres river.

C. D. WALCOTT: The development of Olenellus.

E. W. HILGARD: A new development of mudlump activity at the mouth of the Mississippi river.

H. F. OSBORN: The correlation of the Pleistocene of Europe and North America. The epidermal covering of the trachodont Dinosaurs. Biographical memoir of Joseph Leidy.

W. B. SCOTT: Report of progress in the study of the Miocene Ungulates of Patagonia.

J. M. CLARKE: The austral Devonian.

W. M. **Davis**: Quandaries following from the theory of isostacy.

R. B. **Dole**: Composition of American river waters.

F. W. **Clarke**: A preliminary study of chemical denudation.

George F. **Becker**: Denudation evidence in relation to the age of the Earth.

Franz Boas: The influence of environment on human types.

A. G. **Webster**: A new method for the study of elastic hysteresis.

A. A. **Noyes**: The ionization relations of poly-ionic salts.

Theodore Gill: The structural characteristics and relations of the Apodals. Recent discoveries of the early history of the common eel.

Ira Remsen: Some studies in molecular rearrangement.

R. G. **Aitken**: The number of double stars as a function of the separation of the component.

W. W. **Campbell** and **Sebastian Albrecht**: On the spectrum of Mars as photographed with high dispersion.

W. W. **Campbell**: Second catalogue of spectroscopic binary stars.

2. *Ostwald's Klassiker der Exakten Wissenschaften.* Leipzig, 1909 (Wilhelm Engelmann).—The following are the latest additions to the valuable series of scientific classics :

Nr. 171. Über unendliche Reihen (1689–1704) ; von **Jakob Bernoulli.** Aus dem Lateinischen übersetzt und herausgegeben von Dr. G. **Kowalewski.** Pp. 141, with 12 figures.

Nr. 172. Abhandlungen Jean Rey's, Doktors der Medizin. Über die Ursache der Gewichtszunahme von Zinn und Blei beim Verkalken. Deutsch herausgegeben und mit Ammerkungen versehen von **Ernst Ichenhäuser** und **Max Speter.** Pp. 56, with 2 figures.

Nr. 173. Untersuchungen über die Affinitäten über Bildung und Zersetzung der Äther; von **Berthelot** und L. **Péau de Saint-Gilles.** Annales de Chimie et de Physique (3), lxv, p. 385 ; lxvi, p. 5; lxviii, p. 225. Übersetzt und herausgegeben von **Margarete** und **Albert Ladenburg.** Pp. 242, with 2 tables.

Ektropismus oder die Physikalische Theorie des Lebens ; von **Felix Auerbach.** Pp. iv, 99. Leipzig (Wilhelm Engelmann), 1910.

OBITUARY.

Professor Alexander Agassiz of Harvard University, Cambridge, Mass., died on March 27, in the seventy-fifth year of his age; a notice is deferred until a later number.

Professor Robert Parr Whitfield, curator in the American Museum of Natural History, New York, died on April 6, in his eighty-second year ; a notice will be published later.

Dr. Charles Reid Barnes, Professor of Plant Physiology in the University of Chicago, died on February 24, at the age of fifty-one years.

Professor Samuel Ward Loper, curator of the museum of Wesleyan University, died in March, in his seventy-fifth year. While he published little in geology, he did much to further paleontology in making extensive collections of fishes and plants from the Connecticut Triassic and in the older Paleozoic formations of Texas, Wyoming, and Nova Scotia.

New Circulars.

84: Eighth Mineral List: A descriptive list of new arrivals, rare and showy minerals.

85: Minerals for Sale by Weight: Price list of minerals for blowpipe and laboratory work.

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VOL. XXIX. JUNE, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

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FOURTH SERIES

VOL. XXIX—[WHOLE NUMBER, CLXXIX.]

No. 174—JUNE, 1910.

WITH PLATES II–V.

NEW HAVEN, CONNECTICUT.

1910.

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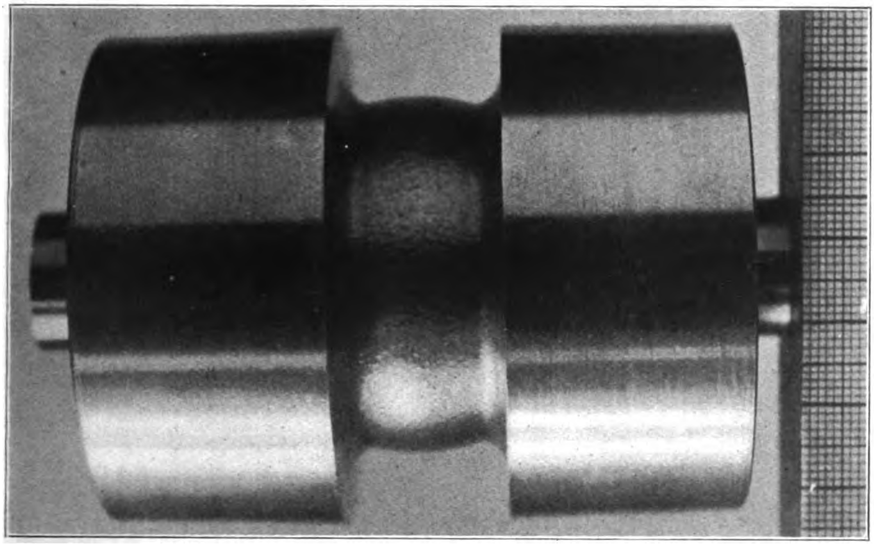
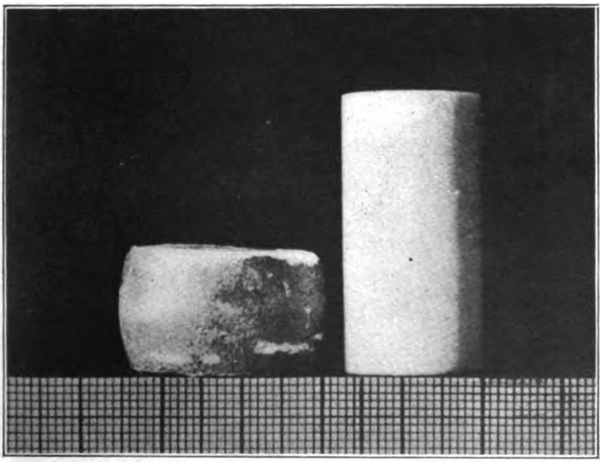


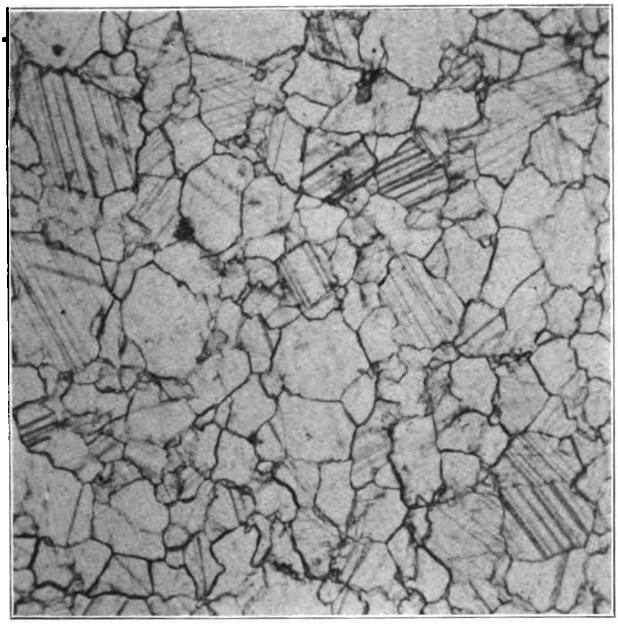
Wrought iron tube enclosing marble column after compression (see below).

b



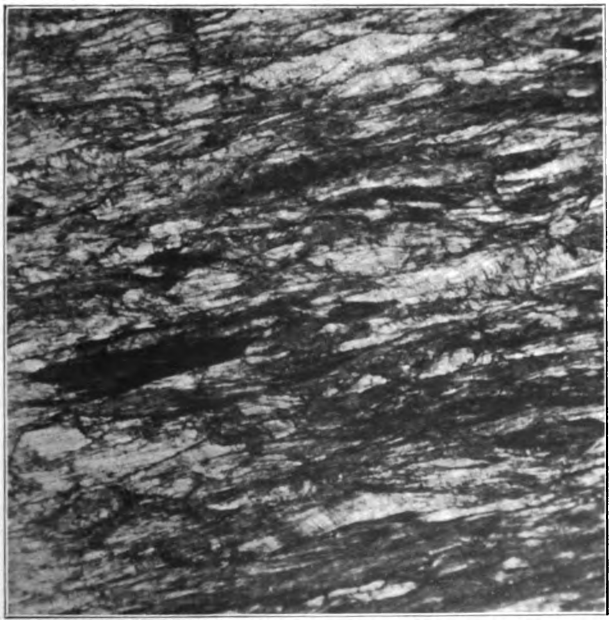
Column of marble before and after compression under a load of 296,725 pounds per square inch (20,875 kilos. per square cent.). The finer lines of the scale are one millimeter apart.

a

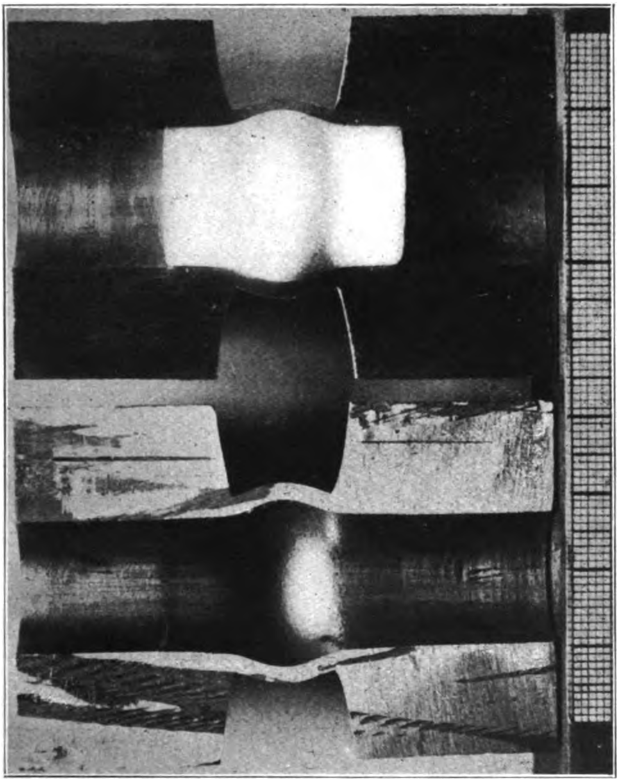


Carrara marble – original. (× 60 diam.)

b



Carrara marble—caused to flow under pressure of 296,725 lbs. per square inch. (× 40 diam.)



Tube with its enclosed column of Carrara marble—cut open after deformation. The finer lines in the scale are one millimeter apart.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLII.—*An Experimental Investigation into the Flow of Rocks, by Frank D. Adams, assisted by Ernest G. Coker. First Paper—The Flow of Marble.* (With Plates II–IV.)

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Introduction.

THAT the rocks of the earth's crust, under the stresses to which they are subjected, have been bent and twisted in the most complicated manner is a fact which was realized by the earlier geologists, and it needs but a glance at an accurate geological section through any highly contorted district of the earth's crust to see that during the folding of the rocks there has often been a marked transfer or "flow" of material from one place to another within the fold.

While, however, these facts are undisputed, the precise nature of this folding and flowing has been a subject concerning which there has been much discussion and a wide divergence of opinion.

Some authorities—among whom Heim,* whose work in the Alps must command the admiration of all, may be mentioned —have held that while in the upper portions of the earth's crust, rocks when submitted to pressure will break, giving rise to faults and overthrusts—the same rocks in the deeper portions of the earth's crust are unable to break up in this way, owing to the great weight of the superincumbent strata. The lines of fracture they hold in this case become smaller and greatly increase in number, the various minerals constituting the rock thus breaking down into grains, which, however, move around and past one another, the adjacent grains always remaining within the sphere of mutual cohesion. The structure of the rock thus becomes cataclastic; but the rock mass, while acting as a plastic body and flowing in the direction of least resistance, maintains its coherence while altering its shape.

Now according to Spring,† the property known as regelation is really due to a power which fragments of bodies have of uniting if brought within the range of the molecular forces, a property which, although possessed in a marked manner by ice, is also, as he has experimentally demonstrated, exhibited by many other bodies and would probably be displayed by all if the required conditions could be attained. The "flow of rocks" would, therefore, according to Heim's view, be a manifestation of regelation on an enormous scale.

Other writers on this subject have maintained that rocks are absolutely destitute of plasticity in any proper sense of the term. Pfaff‡ has even held that in the depths of the earth great pressure will tend rather to prevent molecular movement and thus keep the rocks rigid. Those holding such views attribute the deformation of rocks either to crushing with subsequent recementation of the fragments by mineral matter deposited from percolating waters as the movements proceed or after they are completed,§ or to a continuous process of solution and redeposition of the minerals which make up the rock. The percolating waters, it is held, tend to dissolve material at those points where the pressure is greatest, and to redeposit it where the pressure is wholly or partially relieved; the movements thus being accompanied by a more or less complete recrystallization of the whole rock. Moisture would thus be a necessary factor in all rock folding or contortion, and recrystallization the essential feature of the phenomenon. The deformation of a body of dry rock would be impossible.

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* Der Mechanismus der Gebirgsbildung, p. 31, 1878; see also Van Hise, C. R., Metamorphism of Rocks and Rock Flowage, Bull. Geol. Soc. of America, vol. ix, 1898.

† Recherches sur la propriété que possèdent les corps de se souder sous l'action de la pression; Revue Universelle des Mines, 1880.

‡ Der Mechanismus der Gebirgsbildung, pp. 19–21.

§ Stapff, Zur Mechanik der Schichtenfaltungen, Neues Jahrbuch für Mineralogie, 1879, p. 792; Reyer, Theoretische Geologie, p. 448.

An experimental study* of the subject was undertaken some years since, the rock selected being Carrara marble. The investigation showed that in the case of this rock plastic deformation could be brought about by the action of pressure alone, that heat made the rock more plastic, and that under the conditions of the experiments, the presence of water exerted little or no influence in this respect.

By this it is not meant to imply that when rocks are folded in the earth's crust solution and redisposition do not play a very important rôle. These processes undoubtedly are at work and are widespread in their action. It is quite possible that they are the most important agencies in the folding and flow of rocks.

The experimental study showed, however, that the presence of water was not an essential factor in the development of flow, in the case of marble at least, and that under the experimental conditions, that is to say with the deformation carried out in days, weeks, or at most in a few months, instead of being extended over long periods measured by years or centuries, the deformation of the marble took place quite independent of solution.

It showed furthermore that the structures displayed by highly contorted marbles in many parts of the earth's crust are identical with those produced under the experimental conditions and that they have been developed by the same agencies.

As the subject seemed to be one worthy of further study, the work was continued under a grant from the Carnegie Institution of Washington, and as the investigation went forward it was found to be necessary to follow out several separate lines of research.

The amount of cubic compression which rocks undergo when submitted to pressure from every side was first investigated, all rocks of course being subjected to such compression before deformation.†

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*Adams, F. D., and Nicolson, J. T.—An Experimental Investigation into the Flow of Marble; Phil. Trans. Royal Soc., London, Series A, vol. cxcv, pp. 363-401.

† Adams, Frank D., and Coker, Ernest G.—An Investigation into the Elastic Constants of Rocks, more especially with reference to Cubic Compressibility; Publication of the Carnegie Institution of Washington, No. 46 (Résumé in this Journal, Aug. 1906.)

A further study was then made of the "flow of marble" under widely varied conditions of pressure, temperature and time; after which the investigation was extended to a number of fine-grained and more or less impure limestones; to crystalline dolomites; and then to a series of typical plutonic intrusives—diabase, essexite and granite.

A series of comparative experiments were then made for the purpose of accurately measuring the loads required for the deformation of standard columns of these and other rocks under precisely identical conditions of differential pressure and extremely slow movement.

In the present paper it is proposed to outline the methods employed in these investigations and to present the results obtained by the further study of the "Flow of Marble"; and in subsequent papers to set forth the results obtained in the case of some of the other and more resistant rocks. The results of the investigation as a whole when completed will appear, in extended form and fully illustrated, as a Publication of the Carnegie Institution of Washington.

Methods Employed.

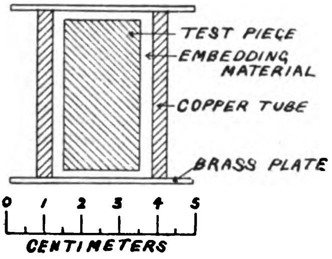
In seeking to ascertain experimentally the action of differential pressure on rocks with a view to reproducing more or less accurately the conditions of pressure which obtain in the deeper parts of the earth's crust, it is manifestly quite useless to attempt to reproduce these conditions by simply submitting the rocks to compression in a testing machine, as is done in testing the strength of materials. There is certainly differential pressure in this case, but it is merely the ordinary atmospheric pressure on the sides of the test-piece, while the tremendous pressure of the testing machine acts in the vertical direction. It is necessary to increase the lateral pressure and make it in some degree at least approach the measure of that exerted in a vertical direction if the pressure conditions of the deeper parts of the earth's crust are to be reproduced. The material must be held in and supported laterally, so that it will not readily break or fracture as the vertical pressure is brought to bear upon it until at least the required conditions of differential pressure have been secured.

In the deformation of rocks within the earth's crust the pressure element which corresponds to this lateral resistance is furnished by the great weight of overlying strata forming the upper portion of the earth's crust, while the direct pressure exerted by the testing machine represents the tangential thrust which folds them.

To secure this lateral resistance, two methods have been proposed. The first is that suggested many years ago by

Kick, in which a stout copper case is prepared within which the specimen is placed, the intervening space being filled by alum, sulphur or some other more or less plastic material, poured in when in a fused condition and which solidifies on cooling. (Fig. 1.) The whole is then submitted to the action of a powerful press and squeezed down. Upon the completion of the experiment the embedding material is removed by heat or solution and the deformed specimen obtained. This method is easily carried out, but it has a number of defects. Thus, the experiments can be carried out only at the ordinary temperature of the laboratory; the lateral resistance offered is not as great as is required in the case of the harder rocks, and it is furthermore impossible to determine the pressure to which the specimen has been subjected, seeing that the load has been divided between the box, the embedding material and the specimen itself.

FIG. 1.



A series of experiments on the deformation of various minerals and rocks were, however, carried out by this method, the results of which are detailed in another paper.*

The second method is that employed by Adams and Nicolson in their investigations on the Flow of Marble. In this a column of the rock is very accurately turned or ground in a lathe and fitted into a heavy tube of steel which has been bored out with equal accuracy to receive it. Pistons of hardened chromium-tungsten steel are then inserted into the ends of the tube, the pressure being transmitted through them to the column enclosed in the steel. By this method a much greater lateral resistance can be secured, which makes it possible to carry out the deformation under much higher

* Adams, F. D.—An Experimental Investigation into the action of Differential Pressure on certain minerals and rocks employing the process suggested by Professor Kick; Journal of Geol., 1910.

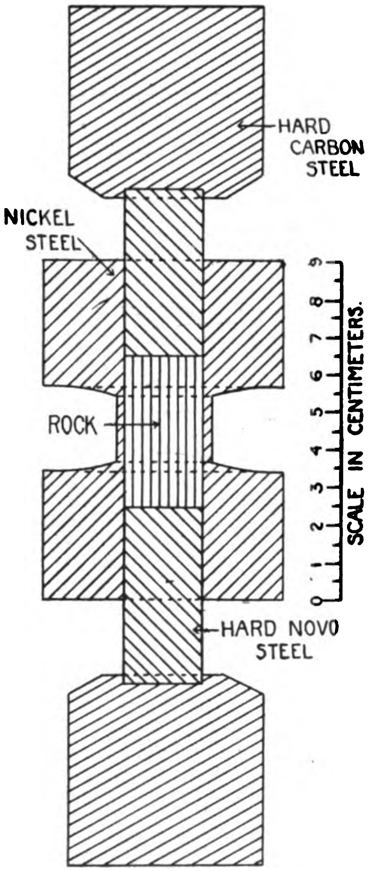
pressures. This resistance also may be varied as desired by altering the thickness of the walls of the enclosing tube, and the pressure under which the rock is being deformed can be accurately measured, seeing that the whole vertical pressure is brought to bear directly upon the specimen. The deformation may, furthermore, be carried on at temperatures approaching even to incipient redness and, if required, in the presence of water or steam.

The material employed in the construction of the enclosing tubes in our earlier experiments was wrought iron or a mild carbon steel, but in all later work a steel containing 4·10 to 5·18 per cent of nickel was employed. This steel has a considerably higher elastic limit than ordinary carbon steel, and our thanks are due to the Bethlehem Steel Company for several consignments of this steel which have been used in the investigation. For the construction of the pistons the chromium tungsten "Novo" steel was employed. This steel when heated to whiteness and plunged into fish oil develops extraordinary strength, a specimen having the dimensions of one of the pistons—namely ·815 inch in diameter and 1·56 inch long—when tested in compression having sustained a load of 215,000 lbs., equivalent to 411,880 pounds per square inch, with practically no alteration of shape. The pistons of this steel may, furthermore, be used under the great pressures employed at temperatures as high as 600° C.

In order that the conditions of differential pressure may be satisfactorily developed, it is necessary to make that portion of the enclosing nickel-steel tube immediately surrounding the central portion of the rock column thinner than it is elsewhere, while leaving the portions of the tube about the ends of the column thicker. This concentrates the flow or deformation of the rock, giving a symmetrical bulge developed within the column and between its extreme ends, and prevents the enclosing tube from opening up under the pressure and permitting the rock to force itself up between the pistons and the ends of the steel tube. As the result of a long series of experiments, too numerous to detail here, it was found that a tube of the dimensions shown in the accompanying drawing (fig. 2) was the most suitable, the thickness of the wall immediately around the central part of the specimen being increased from 25 millimeters to a centimeter according to the amount of lateral pressure or resistance which it is desired to develop, all the other dimensions of the tube remaining the same. The pistons at either end were inserted into heavy steel castings by which the load was transmitted from the press.

The rock columns upon which the experiments were carried out were in most cases about 2^{cm} (·814 inch) in diameter and about 4^{cm} (1·56 inch) long. In the earlier experiments the rock was first ground into rough columns 6^{cm} long and $2·5^{cm}$ in diameter on a rubbing bed. Subsequently a small diamond drill was installed having a hollow bit, which proved an excellent device for readily securing a rough column of any rock which it was desired to use for experimental work. This was then cut into lengths and turned into columns of the required size in a lathe. The final very accurate shaping of the columns was given to them by grinding with an emery or corundum wheel while in the lathe. In this way the little columns were turned to the desired shape with extreme accuracy. They were not as a general rule made exactly cylindrical in shape, but in order to secure a very accurate fit were usually made slightly conical with a taper of 1/1000 of an inch in their length.

Fig. 2.

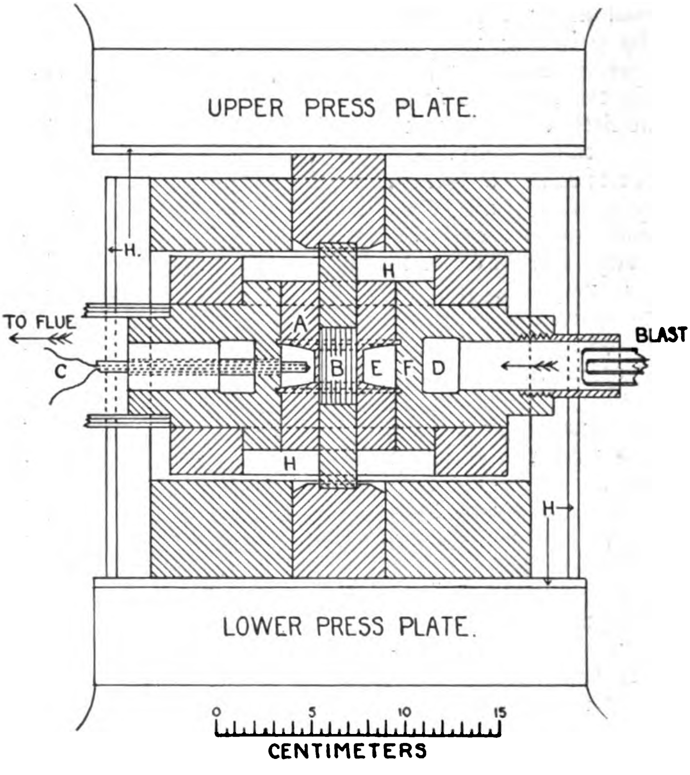


In the same way the steel tube was first turned in a lathe in the usual manner, the inner surface was then ground to secure greater accuracy of shape, and the tube was finally finished by the employment of a reamer. In this way a taper identical with that given to the column was secured, the column, however, being slightly larger than that portion of the tube which was to enclose it. The tube was then heated by placing a red hot iron ring about it and when thus expanded the rock was gently shoved into it to the required position, and the tube being allowed to cool, a mechanically perfect fit of the tube to the column was secured.

When it is desired to carry out the deformation at temperatures above that of the laboratory and up to 600° C. or more, the rock with its tube is enclosed in a small stove of special construction heated by a gas blast, the air being supplied by a Reichhelm blower driven by a 2 h.p. electric motor.

In experimental work formerly carried out on the Flow of Marble at temperatures up to 400° C., a small cast-iron stove was used. As in these later experiments much higher temperatures —up to 1000° C.—have been employed, it was found that in many cases it was extremely difficult to remove the steel tube

Fig. 3.



enclosing the rock from the stove at the conclusion of the experiment, the two having become partially welded together. A stove of cast steel has, therefore, been substituted, made in two parts which are firmly held together by heavy steel collars during the experiment, which collars can be removed at the conclusion of the experiment, allowing the stove to fall apart and access to the enclosed tube to be thus easily obtained. This form of stove has proved very satisfactory. A section of it is shown in fig. 3.

The casting is so arranged that hot gases circulate in an annular channel (D) within it, and outside of the wrought iron cylinder (A), the rock (B) being thus kept at a high temperature while the pressure is applied. The casting is as massive as possible and a very uniform temperature is thus maintained during the whole time of the experiment. The temperature of the enclosed rock is ascertained by means of a platinum—platinum rhodium couple (C), provided with properly calibrated resistance boxes, etc. This lies in the air space (E) by the side of the tube which incloses the specimen. The hot gases are excluded from this space by the wall (F). The whole is well lagged with asbestos, asbestos millboards (H) being also inserted between the bases of the pistons and the plates of the press.

When it is desired to deform the rock at high pressures and temperatures in the presence of water, a modified form of the stove was adopted. The apparatus employed for the purpose has been described in the former paper, to which reference has been made.

Upon the conclusion of the experiment the deformed tube with its enclosed rock was placed in a lathe and the steel tube was carefully turned off until a mere film of metal remained. This was carefully filed through along one line and the enclosed rock was thus obtained intact.

In experiments where very accurate measurement of the pressures employed was required, the large 100-ton Wickstead testing machine set up in the testing laboratory in the Engineering Building of McGill University was employed. In other experiments a series of three hydraulic presses, provided with suitable intensifiers and necessary accessory appliances, were employed. These were calibrated from time to time by direct comparison with the Emery testing machine in the testing laboratory, and the accuracy of their reading thus maintained. The most powerful of these presses, which was the one usually employed, has a capacity of 120 tons.

The Flow of Marble.

In a former paper, as has been mentioned, it has been shown that under conditions of differential pressure marble flows as a plastic body. In the present contribution the results of further experimental work, carried out with the view of obtaining a more complete and thorough knowledge of the behavior of marble under varying conditions of differential pressure, are presented.

1. *Deformation of the dry rock at ordinary temperatures.*

(*a*) *Deformation at comparatively low pressures. Structure of the deformed marble.*

The pressures employed ranged from 120,000 to 130,000 lbs. to the square inch. A series of experiments was first made in which the marble was enclosed in wrought iron tubes. The walls of these tubes immediately surrounding the marble had a thickness varying from 1/8 to 1/4 of an inch, and the load was slowly applied until deformation, indicated by the bulging of the tube, had commenced. So soon as movement ceased the load was increased slightly and the movement was thus resumed, and in this manner the deformation was carried on at a rate which was kept as nearly as possible constant.

The experiments were arranged so that in some cases the deformation went forward rapidly and in other cases very slowly, the time occupied being from ten minutes to sixty-four days.

In later experiments, as has been mentioned, the wrought-iron tubes were replaced by tubes of steel. These latter had the advantage of offering a higher resistance and also of being more easily prepared and more uniform in strength than those of wrought iron. This latter quality was of especial importance in cases where experiments were carried on in series under identical conditions for purposes of comparison. Plate IV shows such a tube with the enclosed marble column, cut open after deformation.

The deformed marble was uniform and compact and seemed to break with equal ease in all directions. It differed somewhat in appearance from the original rock in possessing a dead white color, the glistening cleavage surfaces of the calcite being no longer visible, and the contrast being well brought out when the deformed column is split or cut through vertically, owing to the fact that a portion of the original marble often remained unaltered and unaffected by the pressure. This, when present, had the form of two cones of obtuse angle whose bases are the original ends of the column resting against the faces of the steel pistons, while the apices extend into the deformed marble and point toward one another. These cones, or rather parabolas of rotation, are also developed, as is well known, where cubes of rock, cement or cast-iron are crushed in a testing machine in the ordinary manner. In the present experiments they sometimes constitute a considerable proportion of the whole mass; in other cases they are absent or but faintly indicated; but there is always in immediate contact with the ends of the steel pistons at least a thin cake of marble possessing the character of the ordinary rock.

Thin sections of the deformed column passing vertically through the unaltered cone and deformed portion of the rock were readily made and when examined under the microscope clearly showed the nature of the movement which had taken place. Under the microscope the deformed portion of the rock can be distinguished at once by a turbid appearance differing in a marked manner from the clear, transparent mosaic of the unaltered cone. In that portion of the rock which has suffered deformation the calcite individuals have been squeezed against one another in such a manner that a distinct flattening of the grains has resulted. The individuals are not only flattened, but in some cases distinctly twisted, these movements being effected by the development in the calcite, first of marked strain shadows, and then, where the movement is more intense, by the appearance in each calcite grain of a series of fine parallel lines or very narrow bands giving to it a fibrous appearance, which bands become more numerous as the distortion of the grain becomes more pronounced, the calcite as these bands increase in number displaying a progressive decrease in transparency. When highly magnified, these lines are seen to be due to an extremely minute polysynthetic twinning. The chalky aspect of the deformed rock on the surface of fracture is chiefly due to the destruction by this repeated twinning of the continuity of the even cleavage surfaces of the calcite individuals, thus making the reflecting surfaces much smaller.

By this twinning the calcite individuals are enabled under pressure to alter their shape somewhat, while the flattening of the grains is evidently due to movements along the gliding planes of the crystals.

In the paper by Adams and Nicolson describing the results formerly obtained in the deformation of marble at ordinary temperatures, it was stated that a microscopic examination of the deformed rock revealed the presence of an "anastomozing meshwork of curved and branching lines" of minutely granulated calcite running through the rock, these being lines of cataclastic structure similar to those obtained when marble is deformed by Kick's process. In our more recent experiments, however, this cataclastic structure is seldom found and in many cases is entirely absent. This is probably due to the fact that in this latter work the grinding and fitting of the columns to the tubes has been carried out with the utmost accuracy, while in the former experiments mechanical work was less perfect and the column probably did not in all cases fit its tube perfectly. It is probable that the little lines along which cataclastic structure is developed may have been largely due to a slight shearing of the column before perfect adjustment of the tube had been effected by the pressure to which it was subjected.

A faint but distinct cataclastic structure is, however, found in some cases even when the support offered to the marble by its steel tube is perfect, and along planes of greatest movement the calcite individuals can in some cases be seen to have been apparently slightly torn.

(*b*) *Deformation at very high pressures—Structure of the deformed marble.*

In order to ascertain whether under a greater load the cataclastic structure would entirely disappear, another series of experiments were carried out employing much higher pressures and at the same time carrying the deformation as far as possible. This was secured by increasing the thickness of the wall of the tube which enclosed the marble. A tube of wrought iron built up in the same manner as a gun barrel and having a wall thickness of ·5 inch (12·7^{mm}) for a length of ·625 of an inch (15·875^{mm}) along the central portion of the tube about the enclosed marble column was employed. Steel pistons were then inserted and the pressure applied in the usual way. The tube commenced to bulge when the pressure reached 35,000 lbs. (15,870 kilos.), and the maximum load applied to the marble was 154,000 lbs. (169,750 kilos.), that is to say, a pressure of 296,725 lbs. per square inch (20,875 kilos. per square cent.), the deformation being carried on slowly and occupying forty-one hours. This is equivalent to a depth of 46 miles below the surface of the earth. A photograph of the tube upon the completion of the experiment is shown in Plate II (*a*). Under this tremendous pressure the upper steel piston failed, four radial cracks developing on its face in contact with the marble, thus dividing the piston face into four nearly equal quadrants. These cracks extended up into the piston for approximately half an inch (12·7^{mm}), the largest of them being one one-hundredth of an inch (·254^{mm}) in width at its widest part, and the marble was forced up into these very narrow cracks. Notwithstanding the great thickness of the ends of the tube, moreover, a small amount of the marble under this enormous pressure passed up between the piston and the inner surface of the tube, in a form which while coherent was sufficiently soft to yield to the finger nail with ease. The marble was removed from the bulged tube by turning off the latter in a lathe. That portion of the rock which had not been forced up around the pistons, constituting of course almost the entire mass, was obtained in the form of a slaty cake ·682 inch (17·3^{mm}) in height and 1·135 inch (28·81^{mm}) wide at its widest part, and in form somewhat barrel-shaped. This is shown in Plate II *b* with a column of its original dimensions placed beside it for purposes of comparison. On the surface of this cake no reticulating (Luder's) lines such as those observed when marble is deformed in Kick's experiment are seen.

A series of thin sections of the deformed marble was then prepared. When examined under the microscope these sections show that the marble has had developed in it a most striking and beautiful foliated structure due to the arrangement of individuals of calcite, each of which has been flattened out so that in a section passing vertically through the deformed column it presents the appearance of a ribbon drawn to a point at either end and from eight to ten times as long as it is wide. These elongated calcite individuals are perfectly moulded upon one another, coming together along sharp and gently sinuous lines. A microphotograph of this deformed rock, together with one of the original marble, is shown in Plate III. While many of them possess a very fine polysynthetic twinning, causing them to maintain a generally uniform illumination as they are revolved between crossed nicols, the movement has evidently been chiefly of the nature of a translation or slipping on gliding planes without the development of pronounced twinning, so that the elasticity axes of the various individuals lie nearly parallel to one another, and the whole rock section thus becomes light and dark four times during a revolution between crossed nicols, the periods of extinction being reached when the longer axes of the crystals (i. e., the foliation of the rock) coincide with the vibration planes of the nicols. In sections parallel to the foliation, the flattened individuals are seen to have a rudely polygonal form, often presenting somewhat rhombic outlines, some showing strain shadows which in many cases can be seen to result from a polysynthetic twinning of almost ultra-microscopic minuteness. This is of especial interest, as it is precisely this movement of individual lamellæ of measurable width over one another that gives rise to the phenomenon of the "flow" of metals. Calcite, however, is apparently much more prone to twin during this deformation than metals are, although the greater difficulty of recognizing twinning in metals—the latter being opaque—may have led to the frequency of this phenomenon in their case being underestimated.

The marble shows no trace of granulation and the movement set up in it is an example of perfect plastic flow.

The rock has a distinct foliated structure and the plane of foliation is transverse to the vertical axis of the deformed column, that is to say, at right angles to the direction of pressure in that part of the column between the piston faces, but immediately about the sides of the highly deformed and flattened column the foliation bends up until it runs approximately parallel to the walls, thus following the direction of movement which would be developed in any plastic mass when flowing away from between the advancing pistons in a confined space such as that afforded by the deformation of the enclosing tube. A microphotograph of this deformed marble is shown in Plate III *b*.

Another experiment similar to that just described was carried out with a column of marble of the same size enclosed in a nickel-steel tube with a wall thickness at the thinnest part of ·19 inch (·5^{cm}). This required a pressure of 221,160 lbs. per square inch, which increased the diameter of the column to 36·7 per cent. In this the same structure was developed in the marble as in the case of the experiment just described, but the deformation being smaller, the foliation developed in the rock was not quite so marked.

(*c*) *Strength of the marble after deformation at ordinary temperatures.*

A series of columns of Carrara marble of the size regularly employed, namely 1·575 inch (4^{cm}) long and about ·814 inch (2^{cm}) in diameter, with a slight taper, were prepared and were put into a series of tubes made of a mild carbon steel. The walls of the tube were ·592 inch (1·5^{cm}) thick, except in the central portion of the marble, where for a length of ·688 inch (1·75^{cm}) the wall was thinned away to ·13 inch (·33^{cm}) so as to localize the bulging here. The pistons were then put into the tubes in the usual way and the marble deformed so as to give the column a barrel-shaped form having a diametral enlargement of as nearly as possible ·2 inch (·508^{cm}), or 24·5 per cent. This deformation was produced in one minute, a 100 ton Buckton testing machine being employed. The maximum load required to complete the deformation at this rate of speed averaged about 56,000 lbs. (25,390 kilos.). This very rapid deformation severely tested the steel tubes, a number of them splitting before the required deformation was secured and being therefore rejected. Eighteen such experiments were made, eleven of which were successful, the tube remaining unruptured. The steel tubes were turned off as soon as possible after the conclusion of the experiment and the bulged columns of marble thus set free. Of these the first two having been carefully measured were at once tested in compression to ascertain their strength. In each case the load at which the first splitting of the marble took place was noted and then the load under which the column finally broke down.

The next three columns were allowed to stand for 100 days (or 2400 hours) and were then tested in the same manner. Four others, after having been freed from the enclosing steel

Time of deformation	Number of experiment	Maximum bulge of steel tube (inches)	Maximum bulge of marble (inches)	Time after deformation when tested (hours)	Special treatment	Load at which specimen first split (lbs.)	Load at which specimen broke down (lbs.)	Average load at which specimens broke down (lbs.)	Percentage of original strength	Pounds per square inch
1 minute	108	·228	·242	24	none	3200	4150	4175	60·6	7910
"	115	·174	·211	4	none	3300	4200			
"	111	·196	about ·2	2400	Rest for 100 days	3700	4750	4517	65·7	8558
"	112	·172	" "	2400		3600	4160			
"	113	·174	" "	2400		4300	4640			
"	116	·176	·193	21	Heated to 100° C for 20 hours	2400	3470	3822	55·5	7241
"	117	·214	·225	21		3100	3920			
"	163	·159	·189	77		2550	4000			
"	121	·176	·205	31			3900			
"	119	·175	·213	77	Heated to 350° C for 20 hours	2650	3900	4150	60·3	7863
"	164	·163	·201	77		3520	4400			
30 days	337		·182	2 years	Left in collar		7150	5830	84·7	11,050
"	338		·183	"	"		4920			
"	339		·189	"	"		5420			
Original Marble	177b		·21			Break down suddenly	6780	6886		13,046
"	178		·21				6180			
"	179		·21				7475			
"	180		·24				6140			
"	181		·24				7290			
"	182		·21				7660			
"	183		·21				6460			
"	184		·22				7100			

tube, were heated in a water bath for 24 hours and then tested. The last two, after being freed from the steel tube, were maintained at a temperature of 350° C. for 20 hours and then tested as before.

Eight columns of the original marble, cut to the same barrel-shaped form and having the same average dimensions as those resulting from the one minute squeezes just described, were then prepared, and these also were tested in compression to ascertain their strength. It was found that these, instead of first splitting and then breaking down as in the case of the columns of deformed rock, showed no signs of preliminary rupture, but gave way suddenly and completely.

The results obtained, together with certain others to be referred to later, are given in the table on page 479.

It will be seen that when the marble is deformed in the manner described, the deformation being accomplished in one minute and tested so soon as the enclosing tube can be removed, it retains 60·6 per cent of its original strength.

In order to ascertain whether the deformed marble would be stronger if the deformation were carried out at a higher pressure, a column of the Carrara marble having the same dimensions as those above described was deformed in a heavy tube of nickel steel having a wall thickness of ·197 inch (·5^{cm}) at the thinnest part. The deformation was carried out a little more slowly than in the case of the experiments above described, occupying 100 minutes, and the load required to effect the deformation was 115,000 lbs. Upon the completion of the experiment the deformed column, having been freed from its enclosing tube, was tested in compression and was compared with a column of the original marble cut to the same dimensions. The deformed column measured 1·07 inch (2·72^{cm}) in diameter, which represents a diametral enlargement of 31·4 per cent. The loads required to crush the two specimens respectively were as follows:

Original marble..........	6525 lbs.	(2954 kilos.)
Deformed marble	5470 "	(2479 ")

The deformed marble thus retains 83·8 per cent of its original strength. The experiment was then repeated with three other columns and almost identical results obtained.

It will thus be seen that the increased pressure (accompanied by a somewhat slower rate of deformation) led to a greatly increased strength in the case of the deformed marble, the strength increasing from 60·6 per cent to 83·8 per cent.

In three other experiments an attempt was made to ascertain whether, if the marble were deformed under a still higher pressure, a still further increase in strength might be secured.

The thickness of the tube walls was accordingly increased to 1^{cm}, that is to say, the thickness was doubled. It was found, however, that with a wall of this thickness it was impossible to confine the bulging of the marble to the thinner portion of the tube and thus secure a symmetrical barrel-shaped mass of deformed rock. The pressure required for this deformation was 387,000 lbs. to the square inch (273,000 kilos. per square cm.), and was so great that when subjected to it the marble forced its way up between the pistons and the walls of the tube, and the thin, wedge-shaped ridges so produced broke away and crumbled to powder as the steel tube was being turned off in a lathe.

Attempts were then made, by increasing the length of the marble column and altering the dimensions of the enclosing tube, to prevent the rock forcing its way up between the pistons and the thicker ends of the tube. These attempts, however, were unsuccessful, and it was evident from them that the result could only be accomplished by greatly increasing the thickness of that portion of the walls which enclosed the pistons, which would in its turn necessitate the employment of a much higher pressure to deform the rock, and this would result in the destruction of the pistons themselves. In the case of these experiments under very high pressure, furthermore, it was found that the deformed marble could not be obtained as a solid mass, for so soon as the last thin remnant of the steel tube which was left by the lathe was filed through, the marble developed cracks running across the column at right angles to its vertical axis. In some cases the deformed limestone at once broke in two along one of these cracks. In other cases it was obtained in what was apparently a solid mass, but upon standing a few minutes little transverse cracks, running partially or completely across the specimen, made their appearance. This phenomenon is apparently due to the expansion of the mass upon its relief from the tremendous pressure consequent upon the removal of the enclosing tube and is not confined to marble deformed under very high pressures, but is met with, as will be mentioned, in the case of the various impure limestones and dolomites whose deformation will be described later.

It was, therefore, found to be impossible to test the strength of the marble when deformed at these highest pressures owing to the fact that these transverse cracks invariably developed, thus destroying the continuity of the rock.

(*d*) *Influence of rest and of heat on the strength of the deformed marble.*

It has long been known that iron which has been overstrained, that is to say strained beyond its elastic limit, possesses very different elastic properties from the same iron in its original condition. The iron so treated assumes a more plastic character and a bar thus stretched will on the application of small additional loads undergo a further elongation or creeping, producing a permanent set. It is a well-known fact moreover that iron when thus over-strained will, if allowed to rest for a sufficiently long time, revert to its former state of normal elasticity, and Muir* has shown that this recovery is greatly hastened by raising the temperature of the bar even a few degrees, and if the temperature be raised to 100° C., the reversion to the state of normal elasticity is very rapid, being accomplished in a few minutes instead of requiring several days.

As has been shown, the movement set up in marble under the conditions of deformation secured in these experiments is essentially of the same character as that which takes place in iron or other metals when they are deformed, for while there is in marble, when deformed at ordinary temperatures and at comparatively low pressures, a certain amount of granulation, this is very subordinate to the movement of the calcite on its gliding places or by twinning, as before described. It was therefore conjectured that if the marble was rapidly deformed, thus giving rise to a comparatively weak product, this deformed rock might, following the analogy of the metals, become stronger if allowed to rest for a certain time. If the analogy to metals holds, it might still further be expected that the application of heat would bring about a more rapid recovery of strength on the part of the deformed rock than mere rest alone.

The results of three experiments in which the strength of the deformed column was tested after a rest of 100 days, as well as the results of four other experiments in which the marble after deformation was heated to 100° C. for 20 hours, and two experiments in which the marble after deformation was heated to 350° C. for 20 hours, are given in the table on page 479. As will be seen from an examination of the figures, the marble became distinctly stronger as the result of a rest of 100 days, but the application of heat, whether it be 100° C. or 350° C., does not noticeably accelerate the recovery of strength as it does in the case of the iron. In fact, the figures seem to show that the heating of rock to 100° C. for 20 hours rather weakens it and that it recovers this loss at a higher temperature.

Another series of three experiments was then made in which columns of marble and steel tubes of the same dimensions were employed, but in which the deformation was carried on very slowly, being extended over a period of 30 days, and in which the marble after deformation was allowed to remain in its enclosing steel tube for two years, after which time the steel tube was turned off in the usual way and the marble tested in compression to determine its strength. As will be seen by consulting the table on page 479, under these conditions of slow deformation and long, subsequent rest, the deformed marble is but little weaker than the original rock, its strength being on an average 84·7 per cent of that which it originally possessed, while one of the deformed columns in this series showed a strength greater than the average strength possessed by the columns of the original rock.

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*On the Recovery of Iron from Over-strain, Phil. Trans. Royal Soc., series A, vol. xciii, pp. 1–46.

Another series of three experiments, the results of which were published in a former paper, show that slow deformation alone conduces to increase of strength. In these experiments the deformation was carried on in wrought iron tubes, and at the conclusion of the experiments the tubes, instead of being placed in a lathe and turned off from the enclosing marble, were sawn in two vertically and the half columns of marble thus obtained. These when tested in compression gave the following results:

	Original height	Original diameter	Greatest diameter after deformation	Time of deformation	Crushing load for deformed marble, lbs. per square inch
Experiment A	1·594	1·000	1·407	64 days	5350
" O	1·594	1·000	1·203	1½ hours	4000
" P	1·505	1·000	1·388	10 minutes	2776

These values cannot be used for comparison with those of the former table owing to the fact that the shapes of the test pieces in the two series of experiments were quite different, but compared with one another we see clearly that slow deformation conduces greatly to the preservation of strength.

2. *Deformation of the dry marble when heated to temperatures of 300° C. and 400° C.*

In a former paper an account has been given of the deformation of the marble at these temperatures. Debray* has shown that calcite when heated in closed vessels to a temperature of 350° C. suffers no decomposition, that at 440° C. the decomposition is "insensible," while at 860° C. the disassociation of the molecule of carbonate of lime is marked. In the experiments carried out at 400° C., therefore, it would seem that the marble was deformed at the highest temperature which could be employed without danger of decomposition under atmospheric conditions of pressure.

* Comptes Rendus, 1867, p. 603.

In these experiments, as in the case of those on page 479, the deformation was carried out at comparatively low pressures. The marble after deformation was hard and solid. Tested in compression it was found to be nearly as strong as the original marble. When sliced and examined under the microscope, the rock showed no trace of cataclastic structure, but the grains were seen to be distinctly flattened, giving to the rock a foliation which in some places was very pronounced. The calcite individuals showed the very narrow polysynthetic twinning producing the fibrous appearance before described. The twin lamellæ were in some cases twisted, the twisting being accompanied by strain shadows, which phenomenon, however, in this rock was neither very common nor very striking. The individual grains had to all appearance acted as plastic bodies. A very pronounced movement along gliding planes, coinciding in direction with the course of twin lamellæ, is undoubted. This movement, induced by comparatively low pressures at this elevated temperature, is identical in character with that produced by very high pressures at the ordinary temperatures. In both the movement is due to translation and twinning; breaking or cataclastic structure is absent.

The increased temperature evidently gives the calcite a freer movement on its planes of translation and twinning,—the rise in temperature increases its plasticity. In the case of ice crystals, as is well known, a rise in temperature develops similarly a greater ease of movement along the gliding planes.

3. *Deformation of the marble when heated to 300 C. in the presence of water.*

In the series of experiments formerly made, in addition to heat and pressure a third factor, viz., the presence of moisture, was introduced. A column of Carrara marble enclosed in its iron tube was slowly deformed while at a temperature of 300° C., but in the presence of water vapor under a pressure of 460 lbs. to the square inch (32·33 kilos. per square cm.). The apparatus used for the purpose of this deformation is described in the paper to which reference has already been made. This deformation was carried on very slowly, and at as uniform a rate as possible, the experiment extending over a period of 54 days or nearly two months. Tested in compression, the rock after deformation was slightly stronger than the original rock. Its structure was found to be identical in character with that seen in the case of the marble which had been deformed at 300° C. or 400° C. while dry. A distinct foliation was induced, some of the calcite individuals being three or even four times as long as they were wide. Some few of these flattened grains displayed strain shadows, but no twinning, while the grains in their immediate vicinity showed well-defined twinning, giving rise to the fibrous appearance before described. In some cases a grain showed strain shadows at one end which passed over into a very narrow polysynthetic twinning at the other. The twin lamellæ in many cases are so narrow that even when magnified 1050 diameters they are not very clearly resolved. The individual lamellæ in several sets which were measured were found to have an average width of between ·0005 and ·0006 of a millimeter (·00001968 inch and ·00002361 inch), and some were even narrower.

While the rock was deformed without loss of strength, the presence of water, so far as could be ascertained, did not influence the character of the deformation. It is just possible, however, that there may have been a deposition of infinitesimal amounts of calcium carbonate along very minute cracks or fissures, thus contributing to maintain the strength of the rock. No signs of such deposition, however, were visible.

4. *Specific gravity of the marble after deformation.*

In order to determine whether as a result of deformation under high differential pressures, the specific gravity of the marble was in any way altered, the specific gravity of two specimens of deformed marble was taken as well as the specific gravity of two specimens of the original rock.

The first specimen of deformed marble, "A," had been deformed at ordinary temperatures in a tube of nickel steel 1^{cm} thick, the experiment being carried out in 100 minutes, the pressure required to effect its deformation being 340,000 lbs. to the square inch. The second specimen of deformed marble, "B," had been deformed in a steel tube at a temperature of 400° C. in eight and a half hours at a pressure of 63,000 lbs. to the square inch. Both specimens of the deformed marble when placed in water showed at once that they were traversed by minute fissures, as a considerable amount of air was discharged in the form of minute bubbles. Specimen "A" was allowed to soak in the water until no further bubbles appeared. The rock when so treated was found to have a specific gravity of 2·65. The rock was then placed under water in an air pump. When the pump was worked additional air bubbles appeared, and the rock was allowed to remain under the vacuum until no further air was given off. After this treatment the rock was found to have the specific gravity stated in the accompanying table. In the case of specimen "B," the deformed rock was evidently more solid and compact, as less air was given off. This gives a partial explanation at least for its greater strength, it being evidently freer from minute cracks and fissures.

The following table shows the specific gravity obtained in the case of the various specimens:

	Specific gravity
Original marble—1st specimen.	
Specific gravity after the rock had been placed in water under a vacuum of 28½ inches of mercury for 24 hours	2·722
Original marble—2d specimen.	
After treatment in a similar manner	2·722
Average	2·722
Deformed marble—specimen "A," 1st fragment.	
After having been placed in water under a vacuum of 28 inches of mercury until no further air was given off	2·712
Deformed marble— specimen "A," 2d fragment.	
Treated in vacuo in the same manner for 24 hours, no further air bubbles being given off	2·717
Deformed marble—Specimen "B."	
After having been placed under water in vacuo for 24 hours, until no further air was given off	2·713
Average	2·714
The comparison thus stands:	
Original marble	2·722
Marble after deformation	2·714
Difference	·008

This may be taken to mean that the marble remains unchanged in specific gravity by deformation, but that in the deformed marble some of the little cracks or crevices developed in the rock on relief of pressure still remain, into which the water can not penetrate, and which give rise to the slightly lower specific gravity of the deformed rock. In this connection it is to be noted that specimen " A " could not be tested for strength on account of the minute fissures by which it was traversed and which were developed upon the relief of pressure incident to the removal of the steel tube in which it was enclosed during deformation, while specimen " B," which gave off comparatively few air bubbles, had the appearance of being much more solid.

In connection with these results it is interesting to note the results of the investigations carried out by Spring* on the specific gravity of the sharply folded limestones in the Alps. In these he found that the specific gravity of the limestone on the concave side of a sharp fold, where the pressure of course is greatest, was slightly higher (·003 to ·023) than on the convex side of the same fold. This he at first interpreted as meaning that there had actually been a permanent condensation of the calcite by the greater pressure to which it had been subjected in folding. Further investigation, however, showed that the slightly lower specific gravity of the rock on the outer side of the fold was due to the presence in it of minute rifts or pores which were wanting in the rock on the more highly compressed inner side, the limestone itself really being of the same specific gravity throughout.

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*Note sur la véritable origine de la différence des densités d'une couche de calcaire dans les parties concaves et les parties convexes d'un meme pli; Ann. Soc. Géol. de Belgique, xl, p. 4, 1883-4.

Conclusions.

1. Marble when deformed at ordinary temperatures will flow readily by distortion of the original calcite grains, accompanied, if the differential resistance be low, with the development of a certain amount of cataclastic structure.
2. The marble when deformed at ordinary temperatures will increase in strength if allowed to rest.
3. The marble, if deformed at ordinary temperatures, will be much stronger if the deformation be carried on slowly than if the deformation be rapid. There is every reason to believe that with the extreme slowness of deformation to which the rock is subjected in nature, and the long rest which it subsequently undergoes, the change in shape would be accomplished without any loss of strength.
4. If the deformation be carried on at a higher temperature, the calcite develops freer movement on its gliding planes, and the deformed rock will be relatively stronger than if deformed at the ordinary temperature.
5. Under the conditions to which the rock is subjected in these experiments,—although not under all conditions,—the presence of water has no recognizable influence on the character of the deformation.
6. The specific gravity of the rock is not increased by the pressure to which it is subjected during deformation.

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EXPLANATION OF PLATES.

Plate II.

a. Wrought iron tube enclosing marble column after compression.

b. Column of marble, before and after compression, under a load of 296,725 pounds per square inch (20,875 kilos. per square centimeter). The finer lines of the scale are 1 millimeter apart.

Plate III.

a. Carrara marble, original. × 60.

b. Carrara marble, caused to flow under pressure of 296,725 pounds per square inch. × 40.

Plate IV.

Tube with its enclosed column of Carrara marble, cut open after deformation. The finer lines of the scale are 1 millimeter apart.

ART. XLIII.—*The Heat of Formation of the Oxides of Molybdenum, Selenium and Tellurium; and fifth paper on the Heat of Combination of Acidic Oxides with Sodium Oxide;* by W. G. MIXTER.

[Contributions from the Sheffield Chemical Laboratory of Yale University.]

Molybdenum.

THERMAL chemistry of molydenum is lacking, owing, perhaps, to the difficulty of burning the metal completely in oxygen. It is remarkable, however, that neither Thomsen nor Berthelot recorded any experiments with it. The writer tried burning molybdenum mixed with carbon for ignition and to supply heat to volatilize the trioxide formed, and the result was imperfect oxidation of the metal. Hence the indirect method with peroxide was used.

Metallic molybdenum for the work was prepared as follows: Compact pellets of pure trioxide were heated in an electric furnace in a porcelain tube through which pure dry hydrogen was passed. The metal obtained was in the form of a gray coherent mass and portions adhering to the tube were rejected.[*] It was rubbed up in a mortar and passed through a fine sieve. The purity of the metal was determined as follows: It was oxidized by nitric acid, the acid removed by evaporation and the residue cautiously heated until it ceased to lose weight. The following are the analytical data:

	I	II
Metal taken	1·0505	1·1771
Molybdenum trioxide obtained	1·5750	1·7653
Oxygen taken up	0·5245	0·5882
Molybdenum equivalent to oxygen taken up	1·049	1·1764
Per cent of molybdenum as metal	99·86	99·84

While the results indicate that the reduction by hydrogen was not quite complete, very likely there was some loss in oxidizing the metal or in heating the trioxide. Hence the metal was considered pure and no correction was made for 0·15 per cent of oxygen which the above results indicate. The trioxide obtained dissolved completely in ammonia, showing the absence of silica and alumina.

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[*] Debray (C. R. lxvi, 732) found that molybdenum trioxide affects porcelain at high temperatures. To avoid this the reduction was first tried in a thin platinum tube contained in a porcelain tube. The platinum was made quite brittle and the molybdenum obtained was very slowly acted on by nitric acid. The reason of the action on the platinum was not investigated. In the reduction, where pellets of the trioxide were in contact with the porcelain tube, the porcelain was slightly attacked and the molybdenum adhering to it was found to have taken up a little iron.

The results of burning the metal with sodium peroxide are as follows:

	1	2
Molybdenum	7·000 grams	7·000 grams
Sodium peroxide	25· “	25· “
Water equivalent of system	3,960· “	4,047· “
Temperature interval	3·803°	3·720°
Heat effect	$15,060^c$	$15,055^c$
“ of oxidation of iron	-48^c	-48^c
“ “ oxygen absorbed	-31^c	-52^c
	$14,981^c$	$14,955^c$
For 1 gram of molybdenum	$2,140^c$	$2,136^c$

The mean is 2,138 and for 96 grams of molybdenum it is $205,248^c$.

From this result and the heat of union of sodium oxide with molybdenum trioxide found in experiments 3, 4, and 5, the heat of oxidation of molybdenum to the trioxide is derived as follows:

$$3Na_2O_2 + Mo = Na_2MoO_4 + 2Na_2O + \dots\dots\dots\dots 205{\cdot}2^c$$

$$3Na_2O + 3O = 3Na_2O_2 + \dots\dots\dots\dots 58{\cdot}2^c$$

$$Na_2O + Mo + 3O = Na_2MoO_4 + \dots\dots\dots\dots 263{\cdot}4^c$$

$$Na_2O + MoO_3 = Na_2MoO_4 + \dots\dots\dots\dots 81{\cdot}9^c$$

$$Mo + 3O = MoO_3 + \dots\dots\dots\dots 181{\cdot}5^c$$

Molybdenum trioxide used in the following experiments was heated in a porcelain crucible to expel moisture, allowed to cool in a desiccator and weighed. Sulphur or acetylene carbon was added to the mixture of the trioxide and sodium dioxide to reduce the latter to oxide and also to furnish heat necessary for fusion. It will be observed that where carbon was used the amount of oxygen evolved was large although sodium oxide was formed in excess of the amount equivalent to the molybdenum trioxide. The following are the experimental results:

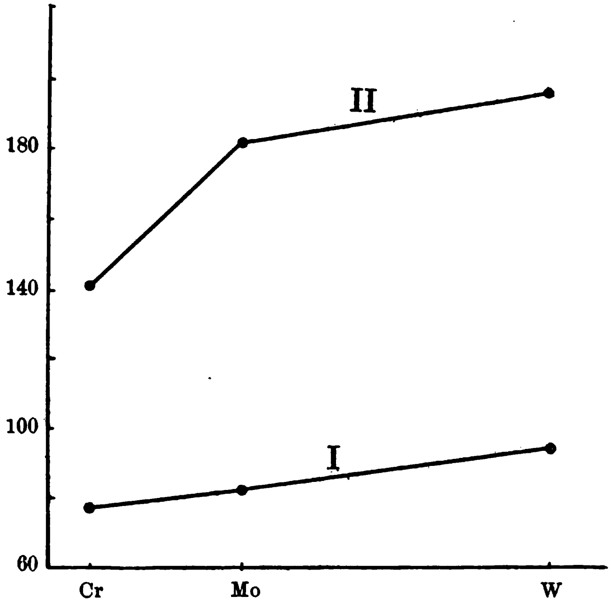
	3	4	5
Molybdenum trioxide	7·501 gr.	5·115 gr.	8·140 gr.
Carbon	0·618 “	0·546 “	
Sulphur	----	----	2·000 “
Sodium peroxide	17· “	12· “	21· “
Water equivalent of system	4,164· “	4,018· “	4,196· “
Temperature interval	2·515°	2·145°	3·616°

Heat effect	$10,472^c$	$8,619^c$	$15,173^c$
" of oxygen set free	$+796^c$	$+362^c$	$+39^c$
" " oxidation of carbon	$-6,876^c$	$-6,075^c$	
" " " " sulphur	----	----	$-10,542^c$
" " " " iron	-48^c	-48^c	-48^c
	$4,344^c$	$2,858^c$	$4,622^c$
For 1 gram of MoO_3	579^c	559^c	568^c

The mean is 569^c and for 144 grams it is $81,936^c$.

It was shown* that the heat effect of $3Na_2O,R_2O_5$, in which R is phosphorus, arsenic or antimony, is closely related to the atomic weights of these elements. The same relation appears in the sub-group of chromium, molybdenum, and tungsten. In the figure the atomic weights are plotted as abscissas and the heats of combination as ordinates. The line I indicates the heat of the reaction Na_2O,RO_3, and II of R,O_3.

FIG. 1.



Molybdenum Dioxide.

Molybdenum dioxide was made by reducing the trioxide as follows: a 100^{cc} pipette was weighed, filled with molybdenum trioxide, heated in an electric furnace to expel moisture, then the tube was closed with stoppers, allowed to cool and weighed. The reduction was made with pure dry hydrogen at temperatures between 410° and 440° approximately. It required 76 hours and in the last four hours the loss was 20 milligrams. The original weight of the trioxide was 49·795 grams and the total loss in weight 6·175 grams. The composition calculated from these data is MoO_2 99·11 per cent and MoO_3 0·89 per cent. It was not deemed best to try to complete the reduction at a higher temperature than used on account of danger of reducing some of the substance to the metallic state. The following are the experimental data:

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* This Journal, vol. xxviii, 103, 1909.

	6	7	8
Molybdenum dioxide......	10·123 gr.	12·028 gr.	12·000 gr.
Sodium peroxide	13· "	15· "	16· "
Water equivalent of system	3,918· "	3,989· "	4,037· "
Temperature interval.....	1·802°	2·085°	2·08°
Heat effect..................	7,060^c	8,317^c	8,397^c
" of oxygen set free......	+1,136^c	+1,117^c	+1,128^c
" " oxidation of iron	—48^c	—48^c	—48^c
	8,148^c	9,386^c	9,477^c
For 1 gram of MoO_2	805^c	780^c	789^c

The fusions were good and dissolved in water with evolution of oxygen and no black residue remained. The oxygen set free in the bomb was collected in a flask over water and the volume of it found by weighing the flask containing it, then filling with water and weighing again. The number of cubic centimeters of oxygen at 0° and 760^{mm} multiplied by 1·73 gave the number of calories lost by the change of sodium peroxide to oxide. If the experimental data above are reduced, allowing for the presence of 0·9 of 1 per cent of trioxide in the dioxide used, the result is not essentially different from that given. The mean for 1 gram of molybdenum dioxide is 791^c and for 128 grams it is 101,200^c.

The following are the results of the experiments with molybdenum:

$Na_2O_2 + MoO_2 = Na_2MoO_4 +$ .... 101,200^c
$Na_2O + O = Na_2O_2 +$ .... 19,400^c

$Na_2O + MoO_2 + O = Na_2MoO_4 +$ .... 120,600^c
$Na_2O + MoO_2 = Na_2MoO_4 +$ .... 81,900^c

$MoO_2 + O = MoO_3 +$ .... 38,700^c
$Mo + 3O = MoO_3 +$ .... 181,500^c
$Mo + 2O =$ .... 142,800^c

Selenium.

Determinations were made of the heat effect when gray metallic selenium is burned with sodium peroxide, using 5 to 10 grams of the former for a test. The mixture fused imperfectly. The water solution of the fusions after acidifying with hydrochloric acid gave no precipitate of selenium when sulphurous acid was added, showing that only selenic acid was present. This was confirmed by the fact that a nitric acid solution of the fusions did not decolorize permanganate. The results for 1 gram of selenium were 1216^c, 1208^c, and 1208^c; average 1211^c. For 79·2 grams it is $95{,}900^c$.

Two combustions were made of a mixture of crystalline selenium dioxide, sodium peroxide, and sulphur. 13·940 and 7·652 grams of selenium dioxide were taken respectively. The results for 1 gram of SeO_2 were 644^c and 588^c. Two other determinations were made, taking 6·118 and 7·109 grams of selenium dioxide and an excess of sodium peroxide. These two fusions were good and oxygen was not liberated, proving conclusively that all of the SeO_2 was oxidized to SeO_3, and that the reaction was $Na_2O_2+SeO_2=Na_2SeO_4$ and not Na_2SeO_3+O. The heat effect for 1 gram of SeO_2 was 617^c and 637^c. The fusion giving 588^c contained some sodium selenite and the result should be discarded. The average of the remaining three is 632^c and of the two highest results it is 640^c. This last number multiplied by 111·2 gives $71{\cdot}200^c$ for the heat effect of Na_2O_2, SeO_2.

The results of the combustions of sodium peroxide are as follows:

$3Na_2O_2 + Se = Na_2SeO_4 + 2Na_2O +$	$95{\cdot}9^c$
$3Na_2O + 3O = 3Na_2O_2 +$	$58{\cdot}2^c$
$Na_2O + Se + 3O = Na_2SeO_4 +$	$154{\cdot}1^c$
$Na_2O_2 + SeO_2 = Na_2SeO_4 +$	$71{\cdot}2^c$
$Na_2O + O = Na_2O_2 +$	$19{\cdot}4^c$
	$90{\cdot}6^c$

The heat of formation of crystalline selenium dioxide derived from these results is $154{\cdot}1-90{\cdot}6=63{\cdot}5^c$. Thomsen's figures are $57{\cdot}1^c$ derived from the heat effect when the dioxide is reduced in hydrochloric acid solution by sodium hydrosulphide and also from the heat of formation of $SeCl_4$ and its hydrolysis. His results by the two methods are practically identical. Thomsen used amorphous selenium and the writer the grey metallic modification, and as the change of the amorphous form into the crystalline evolves heat the writer's results would have been a little higher had he used amorphous selenium. The reason for the difference of $6{\cdot}4^c$ between Thomsen's result and the writer's is not apparent. He stated that the hydrolysis of $SeCl_4$ is complete and is probably right in this view since selenium dioxide dissolves in dilute hydrochloric acid without appreciable heat effect.

R. Metzner* found the heat of H_2SeO_4,Aq to be the same as that H_2SO_4,Aq. On the assumption that the heat effect of SeO_3,H_2O is the same as SO_3,H_2O, he calculated that $Se+3O=42{\cdot}1^c$, using $Se,3O,Aq=76{\cdot}660^c$ (T). That is, $SeO_2+O=-14{\cdot}4^c$. This explains, according to Metzner, why SeO_3 can not be isolated. The view that SeO_2+O is an endothermic reaction accords with the results of the experiments with sodium peroxide. The observed heat effect of Na_2O_2,SeO_2 is $90{\cdot}6^c$; adding $14{\cdot}7^c$, the heat absorbed by the oxidation of SeO_2 gives $105{\cdot}3^c$ for the heat effect of Na_2O,SeO_3. If we consider $Se,2O=63{\cdot}5$ and subtract $14{\cdot}7^c$ we have for $Se,3O=48{\cdot}8^c$ and

$Na_2O + Se + 3O =$ .... $154{\cdot}1^c$
$Se + 3O =$ .... $48{\cdot}8^c$

$Na_2O + SeO_3 =$ .... $105{\cdot}3^c$

This result is identical with that found from the reaction between Na_2O_2 and SeO_2, but substituting another number for 14·7 in the calculation will give equal numbers. The heat of formation of Na_2SeO_4 in solution calculated from Thomsen's data is $262{\cdot}3^c$; subtracting 99·8 for the heat effect of $2Na,O$ gives $162{\cdot}5^c$ for $Na_2O,Se,3O$. The heat of solution of Na_2SeO_4 has not been determined but it is negligible, as a rough test with 15 grams of Na_2SeO_4 in 200^{cc} of water gave a rise of approximately $0{\cdot}1^c$. The writer is unable to explain why $154{\cdot}1^c$ obtained by burning selenium with sodium peroxide is so much lower than the number derived from Thomsen's experiments.

It should be stated that attempts were made to determine the heat of formation of selenium dioxide by burning in a bomb a mixture of selenium and charcoal. In one instance the bomb was filled with a crystalline mass of selenium dioxide, but the combustion was incomplete. In other experiments the mixture burned only on the surface.

Tellurium.

The tellurium used in the work was purified by dissolving the crude metal in acid and making a fractional precipitation with sulphur dioxide or by recrystallizing the nitrate. The precipitated tellurium was fused in hydrogen. Tellurium and

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[*] Ann. Ch. Phys. (7), xv, 225.

its dioxide do not burn well with sodium peroxide and sulphur was added to supply the heat requisite for combustion. Tellurium dioxide was obtained by heating the nitrate and fusing the residue. Telluric acid was prepared by Staudemaier's* method by oxidizing the dioxide with chromium trioxide. The telluric acid was slowly heated in an electric furnace to 375–400° and until a sample did not yield water on melting. The per cent of trioxide was calculated from the loss of oxygen on heating a weighed portion until the weight was constant. It was considered better to correct for tellurium dioxide present than to attempt to remove it by hydrochloric acid. Two different preparations of tellurium trioxide were used. That for Experiment 5 contained 80·8 per cent of trioxide, and for 6, 91·3 per cent. The following are the experiments:

	1	2
Tellurium	5·000 grams	6·000 grams
Sulphur	1·000 “	1·000 “
Sodium peroxide	20· “	30· “
Water equivalent of system	3,866· “	4,032· “
Temperature interval	2·883°	3·096°
Heat effect	11,146^c	12,483^c
“ “ of sulphur	—5,271^c	—5,271^c
“ “ “ iron	—48^c	—48^c
“ “ “ oxygen absorbed	—34^c	—34^c
	5,793^c	7,130^c
For 1 gram of tellurium	1,159^c	1,188^c

The result for 127·5 grams of tellurium is 149,700.

	3	4
Tellurium dioxide	10·000 grams	10·000 grams
Sulphur	1·000 “	1·000 “
Sodium peroxide	21· “	21· “
Water equivalent of system	3·906· “	3·896 “
Temperature interval	2·968°	2·978°
Heat effect	11,593^c	11,602^c
“ “ of oxygen evolved	+51^c	+110^c
“ “ “ sulphur	—5,271^c	—5,271^c
“ “ “ iron	—48^c	—48^c
	6,325^c	6,393^c
For 1 gram of tellurium dioxide	633^c	639^c

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* Zeitschr. anorgan. Chem., x, 189.

The result for a gram molecule of tellurium dioxide is $159·5 \times 636 = 101·400^c$.

	5	6
Substance taken	10·060 grams	6·000 grams
Composition of substance TeO_2	8·209 “	5·478 “
Composition of substance TeO_3	1·951 “	0·522 “
Sulphur	1·000 “	0·800 “
Sodium peroxide	16· “	14· “
Water equivalent of system	3,963· “	3,152· “
Temperature interval	2·802°	2·537°
Heat effect	$11,104^c$	$7,996^c$
“ “ of oxygen evolved	$+1,072^c$	$+636^c$
“ “ “ TeO_3	$-1,241^c$	-332^c
“ “ “ iron for ignition	-48^c	-48^c
“ “ “ sulphur	$-5,271^c$	$-4,216^c$
“ “ “ TeO_2	$5,616^c$	$4,036^c$
For 1 gram of TeO_2	684^c	737^c

The mean of the results is 708, which gives for the reaction $Na_2O + TeO_2 = Na_2TeO_4 + 175·5 \times 708 = 124,300^c$.

Summary of results.

$3Na_2O_2 + Te = Na_2TeO_4 + 2Na_2O +$ .... $149·7^c$
$3Na_2O + 3O = 3Na_2O_2 +$ .... $58·2^c$

$Na_2O + Te + 3O = Na_2TeO_4 +$ .... $207·9^c$
$Na_2O + TeO_2 = Na_2TeO_4 +$ .... $124·3^c$

$Te + 3O = TeO_2 +$ .... $83·6^c$

$Na_2O_2 + TeO_2 = Na_2TeO_4 +$ .... $101·4^c$
$Na_2O + O = Na_2O_2 +$ .... $19·4^c$

$Na_2O + TeO_2 + O = Na_2TeO_4 +$ .... $120·8^c$

The heat of formation of crystalline tellurium dioxide is $207·9 - 120·8 = 87·1$. Thomsen's result of $77·2^c$ for TeO_2Aq is too low since $TeCl_4$ does not hydrolyze completely. The result of experiments 5 and 6 giving $124·3^c$ for the heat of combination of Na_2O and TeO_2 is to be considered as approximate only on account of the large correction for oxygen set free, and hence the heat of formation of TeO_2 derived is to be regarded as an approximation. Since the trioxide and dioxide of tellurium give nearly the same heat when fused with sodium peroxide, it is evident that the oxidation of crystalline

TeO_2 is accompanied by little or no heat effect. The results indicate that the reaction is slightly endothermic.

The heat effect of Na_2O,SO_2 derived from Thomsen's data is $125{\cdot}6^c$ and from the writer's* $123{\cdot}7^c$. That of Na_2O,TeO_2 is 124·3 approximately. If we take $162{\cdot}5^c$ based on Thomsen's results and subtract $Se,3O = 42{\cdot}4^c$, we have $120{\cdot}1^c$ for Na_2O,SeO_2. The heat of the reaction Na_2O,RO_2 where R is sulphur, selenium or tellurium, is probably nearly the same in all cases. This much is however, evident, that it does not increase or diminish notably with increasing atomic weights as it does in the reaction Na_2O,R_2O_5 where R is phosphorus, arsenic, antimony, and bismuth,† or in Na_2O,RO_3, where R is chromium, molybdenum and tungsten. Moreover the heat effect of Na_2O-RO_2 is in all cases higher where R is sulphur, selenium or tellurium, than where R is chromium, molybdenum or tungsten.

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* This Journal, vol. xxvi, 125.

† Loc. cit.

ART. XLIV.—*Contributions to the Geology of the Grand Canyon, Arizona.—The Geology of the Shinumo Area* (continued); by L. F. NOBLE. (With Plate V.)

Part II.

GENERAL GEOLOGY (*continued*).
  Algonkian—Grand Canyon Series.
    Name.
    Distribution in the Grand Canyon.
    Stratigraphic Position, Structure, and Distribution in the Shinumo Area.
    Sediments of the Unkar Group.
      Preliminary Outline.
      Detailed Section.
      Comparison with the Type Section in Unkar Valley.
  Diabase Intrusive in the Unkar.
    Occurrence.
    Petrography.
    Variations in character.
    Contact Metamorphism.
    Conclusions.
  Age and Correlation.
GEOLOGIC HISTORY.
BIBLIOGRAPHY.

ALGONKIAN.

Grand Canyon Series.

Name.—The unaltered pre-Cambrian sedimentary rocks of the Grand Canyon region were first studied by Walcott (Walcott, *b*) at the eastern end of the Kaibab division of the Canyon. They are described as a series of sedimentary rocks, 12,000 feet in thickness; comprising limestones, shales, sandstones, and interbedded flows of lava; separated both from the underlying Vishnu schists and from the overlying Cambrian sediments by profound unconformities; and exposed over a considerable area in the greater depths of the Grand Canyon and in the inter-canyon valleys of the north side. To this series of sedimentary rocks the name "Grand Canyon series" was given by Walcott. A slight unconformity of erosion was found to occur in the middle of the series. The strata lying below this minor unconformity were designated as the "Unkar terrane," while those lying above it were designated as the "Chuar terrane." The Unkar terrane derives its name from Unkar valley, in which these strata are typically exposed. The Chuar terrane is named from its typical exposures in Chuar valley. These two valleys are parallel inter-canyon valleys of the north side of the Colorado river in the area described by Walcott.

Distribution in the Grand Canyon.—There are six localities within the Grand Canyon between the mouth of the Little

Colorado in the eastern end of the Kaibab division and the mouth of Tapeats Creek some 80 miles below in the eastern end of the Kanab division, where the strata of the Grand Canyon Series are exposed between the crystalline schists of the Archean and the basal Tonto sandstone of the Cambrian. The location of these exposures is shown on the map accompanying this article. Five of the localities are within the Kaibab division; the sixth is within the Kanab.

The first of these localities is the classic area below the mouth of the Little Colorado described by Walcott. This is the largest areal exposure of these rocks in the Grand Canyon, and includes both the Unkar and Chuar groups.

The second locality lies five miles west of the first at the head of the inner gorge of Clear Creek on the north side of the Colorado river within the depths of the Ottoman Amphitheater. The exposure is limited to less than a square mile. It comprises a small portion of the basal Unkar and is structurally a unit with the first locality.

The third locality lies along the north side of the Colorado river at the mouth of Bright Angel Creek opposite the railroad terminus and hotels of the Sante Fe Railroad. About 1000 feet of the basal portion of the Unkar group are there represented and the areal extent of the exposure is about three square miles. This locality has been briefly described by Ransome (Ransome, *a*). It lies about 10 miles west of the type locality.

The fourth locality comprises a limited exposure of basal Unkar strata which lies in the depths of the Hindu Amphitheater on the north side of the Colorado river about three miles up Crystal Creek from its mouth. It is situated some 20 miles west of the type locality. The areal extent of the exposure is about one square mile. It is as yet undescribed.

The fifth locality lies about the mouth of Shinumo Creek about 30 miles west of the exposures of the type area. It comprises about 12 square miles in areal exposure and represents nearly the entire thickness of the Unkar group. It is hitherto undescribed in geological literature and is the subject of the succeeding pages of this article.

The sixth locality is situated on the Colorado river just above the mouth of Tapeats Creek in the eastern end of the Kanab division of the Canyon, about 12 miles northwest of the mouth of the Shinumo in a direct line and about 25 miles down the river in its actual course. The length of the exposure is about three miles in the bed of the river and in its narrow gorge beneath the Tonto sandstone. About 4,000 feet of the basal portion of the Unkar group are exposed, striking N.W.-S.E. and dipping about 15° N.E. This locality is structurally a unit with the exposures of the Shinumo area. It is unmentioned in geological literature.

In the western end of the Kanab division in a section across the Grand Canyon at the foot of Toroweap valley, 50 miles west of the Shinumo area, Dutton figures "rocks of Silurian and Archean unconformable" in the bed of the river beneath the basal Tonto sandstone of the Cambrian (Dutton, *a*, p. 88). It is probable that these "Silurian" rocks there represent the Grand Canyon series.

Whether these rocks appear at places in the Shivwits division between the Vishnu schist and the Tonto sandstone is not at present known.

Stratigraphic position, structure, and distribution in the Shinumo Area.—Two unconformities determine the stratigraphic position of the sediments of the Grand Canyon series in the Shinumo Area: they are separated from the underlying Vishnu schists of the Archean by a profound unconformity which represents a base-leveled surface of erosion, and from the overlying Tonto sandstone of the Cambrian by an unconformity which represents a similar base-leveled surface above.

The strata of the Grand Canyon series here constitute a wedge-shaped mass whose apex lies along the south side of the Colorado river parallel to its northward course in this part of the area. The mass as a whole constitutes one great tilted block, which in turn consists of a great number of minor tilted and rotated blocks pitching at successively greater angles northeast away from the apex of the wedge, until at a distance of three miles from the Colorado river the whole mass is dropped by a profound fault which brings up the underlying Vishnu schist from a great depth,—a structure which strikingly resembles that of the area of similarly faulted Triassic blocks of the Connecticut valley. The strike of the strata is N. 40° W. The dips are variable: in general the strata of the fault blocks near the apex of the wedge dip 10°–15° N.E.; near the center of the wedge the dips average 25° N.E.; while in proximity to the line of the great limiting fault on the northeast they are completely reversed by the "drag" along the fault plane. The truncation of this pre-Cambrian structure by the unconformity at the base of the Tonto sandstone is absolute.

The great pre-Cambrian fault that limits the wedge upon the northeast represents the exposure in the basement rocks of the line of displacement of the West Kaibab fault and displays in the most spectacular manner a phenomenon analogous to that described by Walcott upon the line of the East Kaibab monocline (Walcott, *a*). Upon the line of the ancient fault in the Shinumo area two later displacements have taken place after the deposition of the entire Paleozoic series of the Canyon wall and probably later strata. The first of these is a monoclinal flexure which reverses the throw of the pre-Cambrian fault, while the second is a still more recent fault superimposed upon the line of the monoclinal flexure.

The strata of the Grand Canyon series are exposed beneath the Tonto sandstone in all that part of the inner gorge of the Muav-Flint Creek canyon which is on the south side of the great pre-Cambrian fault,—a distance of about three miles. They are exposed for three miles in the gorge of the Shinumo Canyon; for seven miles along the north side of the Colorado river; and in all the inter-canyon valleys within that distance which are eroded below the base of the Tonto sandstone. The two largest of these inter-canyon valleys are the "East Wash," a mile east of the Shinumo, and the "Asbestos Canyon," three miles to the west.

The gorge of the Colorado river has everywhere been trenched to a depth sufficient to expose the Vishnu schists along the river beneath the overlying strata of the Grand Canyon series. This is due to the fact that the course of the river lies close along the southern apex of the wedge.

The exposures on the south side of the river are more limited, due to the thinning out of the wedge in that direction and the lack of inter-canyon valleys trenched beneath the Tonto sandstone. The strata are exposed for two miles above and one mile below a point opposite the mouth of the Shinumo.

A southwestward bend in the river in the western part of the area carries it beyond the apex of the wedge, below which point the Tonto sandstone caps the Vishnu schists which lie in the river gorge. Southeastward up the river, in the eastern part of the area, a similar relation obtains.

The hard middle members of the Unkar resisted the erosion which preceded the deposition of the Cambrian sandstone and stood as an island in the Tonto sea.

This long monadnock of quartzite runs across the area in a N.W.–S.E. direction parallel to the general strike of the strata of the wedge, and a narrow outcrop of these quartzites is exposed along the Tonto platform on the north side of the river just at the base of the Redwall cliff, running for a distance of about five miles beyond the main areal exposures about the mouth of the Shinumo and uniting with the limestones of the upper Tonto group to form the lower part of the great cliff of Redwall limestone. In the eastern part of this exposure the quartzite monadnock projects 700 feet above the base of the Tonto sandstone. Westward from the exposures about the Shinumo the prolongation of the monadnock along the strike of the quartzites exposes them in a narrow outcrop upon the Tonto platform one mile west of the Shinumo.

The total areal exposure of the Grand Canyon series in the Shinumo area is about 12 square miles.

In following up the Shinumo from its mouth to the point where it leaves the lateral gorge of the Muav-Flint Creek canyon, a traverse is made of the total exposed thickness of the Unkar group from the unconformity at the base to the highest member that is limited by the profound fault on the northeast. There can hardly be a more magnificent illustration of details of geological structure than is here revealed. Along the entire western side of the Shinumo canyon, in cliff faces a thousand feet above the bed of the stream, is displayed every detail of the structure beneath the basal Tonto sandstone. Westward down the Colorado river the intersection of the two great unconformities forming the apex of the wedge is seen in the cliff face above the river bank, below which point the river narrows in its somber gorge in the Vishnu schists. From here northeastward, in the cliff faces along the western wall of the Shinumo canyon, bed after bed of the Unkar strata appears, wedging out southwestward beneath the plane of the unconformity beneath the Tonto sandstone. Every detail of the successive fault blocks of the great wedge is clearly shown,—their increasing tilt northeastward, the dips of the fault planes that bound them, and the occasional down-dropped wedges. Above runs the plane of the pre-Tonto unconformity, revealing in cross section the monadnock in this peneplain which existed as a rocky island during the inroads of the Tonto sea, the debris from its wave-cut cliffs being incorporated and preserved to the minutest detail in the Tonto sandstone. In the background, bed above bed in conformable succession, lies the horizontal Paleozoic section in the wall of the mile-deep Canyon. After traversing a thickness of 5800 feet of Unkar strata in a distance of three miles dipping northeastward into the bed of the stream, the traveler crosses the line of the great pre-Cambrian fault of more than 5800 feet and comes once more into the Vishnu schists on the farther side of the Muav-Flint Creek canyon.

Here again is an instance of the simplicity with which the geological structure is revealed in this wonderful country. Along the whole northern wall of the lateral gorge lie the Vishnu schists below the Tonto sandstone cliff. On the southern side, at the same level, lie the upper sandstones of the Unkar, their beds dragged up sharply against the fault line, which lies in the bed of the stream. The whole Paleozoic system on the northern side of the gorge has been dropped 500 feet by the torn monocline of the West-Kaibab fault, reversing the throw of the pre-Cambrian fault on the same line in the basement rocks. Looking westward up the Muav Canyon, the beds of the Paleozoic are seen bending down against the fault line in a graceful arc. Far up the canyon at its head under the Muav Saddle, the more recent fault has reversed its throw and restored the throw of the monoclinal flexure. There is not a detail of this structure that may not be seen at a glance.

SEDIMENTS OF THE UNKAR GROUP.—LITHOLOGY.

Preliminary Outline.—The pre-Cambrian sedimentary rocks of the Shinumo area represent the greater part of the Unkar group of the Grand Canyon series of Algonkian age. The upper, or Chuar, group is not represented in the area. Although these sediments present no more evidence of alteration or metamorphism, aside from local igneous contact phenomena, than the overlying beds of the Paleozoic, they are destitute of fossils or decisive evidence of life. In the absence of fossils the natural basis for dividing the group into component members is the lithology. On this basis the Unkar group in the Shinumo area is divisible into five members, succeeding each other in conformable stratigraphic succession. It is not intended that the importance of this division should be greatly emphasized. Its chief value lies in the fact that it furnishes a basis for comparing the lithological succession of the Unkar group in this area with that in the type locality described by Walcott 30 miles to the east, as well as a basis for distinguishing in a broad way the main changes in the physical conditions under which these sediments were laid down.

At the base, resting upon the profoundly eroded and base-leveled surface of the metamorphic rocks of the Vishnu series,

Synopsis.

Tonto Group Unconformity.		
Unkar Group.	5. Micaceous shaly sandstone (exclusive of 36 feet of intrusive rock)	2297
	4. Sandstone and quartzite	1564
	3. Argillaceous and arenaceous shale (exclusive of 950 feet of intrusive rock)	580
	2. Calcareous shale and limestone	335
	1. Basal conglomerate	6
	Total	4782 ft.
Unconformity Vishnu series.		

is a thin conglomerate. This constitutes the basal member of the Unkar. Overlying the conglomerate is a series of limestones and calcareous shales. These grade upward into argillaceous and arenaceous shales which are intruded by a thick sill of diabase, and are succeeded in turn by great thicknesses of sandstone and quartzite. The uppermost exposed member of the group in the area is a thick series of micaceous shaly sandstones.

It has been shown that these strata lie in a wedge-shaped mass inset in the Vishnu schists, and that this wedge is composed of a great number of smaller titled fault blocks. It is apparent from this relation that nowhere in the Shinumo area can the thickness be measured in one unbroken section. Since, however, the lithological characters of the strata are constant and easily recognized, and since the throw of the faults that bound the titled blocks seldom exceeds 100 feet, the restoration of a section showing the unbroken sequence is not a matter of great difficulty.

Detailed sections were made upward from the base of the Unkar through each fault block until its limiting fault was reached. The highest bed measured was then located in the next block to the northeast, and the measurement resumed at that point. Except in the fifth, or highest member of the group, all sections were measured with a tape along the nearly vertical wall faces of the box canyons of the Shinumo and other washes that cut across the strike of the strata. In the fifth, or highest member of the group, the strong drag of the great fault on the northeast has flexed and contorted these shaly sandstones in such a manner that accurate measurement with the tape alone was impossible. Their thickness was computed by the aid of trigonometric formulæ, using the combined data afforded by the use of the tape, the topographic map, and observations of the varying strike and dip.

The section incorporated in this article was made in two places. The greater part of the total thickness was measured in a traverse up the Shinumo. This section includes all the strata above the diabase sill which is intruded midway in the "arenaceous and argillaceous shales" which comprise the third member of the Unkar. It would have been perfectly possible to make a complete section of the group in a traverse of the entire course of the Shinumo from the basal unconformity at the mouth of the creek to the great fault three miles above, although four faults cross the creek between its mouth and the place where the diabase sill dips beneath the bed of the stream. But a place was found in the canyon of the East Wash where all the strata between the basal unconformity and the diabase sill lie in a continuous unfaulted section, in a fault block that is tilted about 10° N.E. The section of the basal members of the group was measured in this locality, where the sequence is unbroken by faulting.

Detailed Section.

First Member.—Basal Conglomerate. The surface represented by the upper unconformity that separates the Unkar group from the basal Cambrian is a striking enough example of a base-leveled surface, although monadnocks rise in places to a height of 700 feet above the base of the Tonto sandstone. But the surface represented by the lower unconformity that separates the Unkar group from the Vishnu is an almost perfect plane: nowhere in the seven linear miles exposed in the Shinumo area can a difference in relief be observed that exceeds 20 feet. The depth of weathering below this surface appears to be slight, in spite of the enormous amount of rock that has been removed, and the weathering appears to be the result of physical disintegration rather than of chemical decomposition.

The basal conglomerate is an arkose conglomerate varying in thickness from 1 to 6 feet in the Shinumo area. It is composed of angular or subangular fragments of the rocks of the underlying Vishnu series, cemented by a matrix of red arkose mud which usually contains small fragments of pink feldspar. Occasionally the matrix contains small rounded grains of quartz.

The degree of induration of this conglomerate presents all variations from a hard, dense, siliceous rock, which fractures across matrix and enclosed rock fragments alike, to an easily disintegrated rock in which the matrix crumbles away from the enclosed fragments. This phenomenon, however, does not depend upon original cementation, but upon metamorphic effects produced by the diabase sill that is intruded in the overlying rocks, the degree of induration depending upon how far the conglomerate lies below the contact of the sill.

The matrix is usually of the same composition everywhere in the area. The character of the enclosed fragments, however, is sharply localized by the character of the underlying rock. The rock which underlies the conglomerate in the East Wash is the quartz-diorite of the batholith previously described. For three feet below the conglomerate the diorite is weathered along the joints into roughly angular blocks. These joints are filled with the red arkose material of the matrix. Above follows a layer of the conglomerate one foot in thickness, composed of weathered fragments of the diorite cemented with the red arkose material. Then follows a layer six inches thick composed of small rounded quartz pebbles and fragments of chert of the same character as that contained in the overlying limestones. The whole is cemented with the red mud. The conglomerate is very little indurated in this locality. Although the contact of the diorite with the mica-schists in the underlying Vishnu is not two hundred yards distant, there is not a fragment of the mica-schist to be observed in the conglomerate.

In the Asbestos Canyon, four miles to the west of the East Wash, the underlying rocks are mica schists and veins of quartz and pegmatite. Here the Vishnu schist is scarcely weathered at all below the unconformity. The overlying conglomerate is 6 feet thick and consists of angular fragments of the underlying mica-schists, fragments of pegmatitic feldspar and vein quartz, and the arkose cement described above. The degree of induration is here very great, and the rock fractures across the grains like a hard, dense quartzite. This is due to the fact that the lower contact of the diabase sill lies only 150 feet above this basal conglomerate in the Asbestos Canyon, while in the locality in the East Wash it lies 550 feet above.

Two important features characterize the basal conglomerate of the Unkar in the Shinumo area; the arkose nature, and the lack of sorting and transportation of the component fragments.

Second Member.—Calcareous Shales and Limestone. The section was measured on the west side of the canyon of the East Wash. This and all the following sections read from the base upward, *a.* 1 being the bottom bed, overlain by *a.* 2, etc.

CHARACTER	THICKNESS
a. Basal white limestone.	
1. White, nodular, cherty limestone. The chert occurs in nodules with a roughly concentric structure somewhat suggestive of the structure of Cryptozoön	1′ 6″
2. White, cherty limestone carrying the chert in thin parallel bands which are etched out by the weather on the cross sections. The surface of each chert layer shows polygonal cracks suggestive of sun-cracks in shale. This structure belongs to each separate chert layer and is not a columnar structure. The weathered surfaces of these chert layers are dotted with small cubic depressions which were apparently formed by the leaching out of some mineral of a cubic habit	4′ 6″
Total	6′

	Character	Thickness
b.	*Argillaceous and calcareous red shale and limestone.*	
1.	Soft, purple shale	6″
2.	Purple, cherty limestone	1′
3.	Purple shale with occasional bands of purple calcite	4′
4.	Purple, crystalline limestone	1′
5.	Alternating layers of buff and chocolate-red shale with a splintery habit of weathering and a roughly concretionary structure. Like all the succeeding shales and sandstones of the Unkar they are mottled with light-colored spots which are usually circular or elliptical in form and of all sizes	5′ 6″
6.	Blue limestone, white for 1″ at the base and showing dendritic markings	5″
7.	Red shale	1′ 5″
8.	Blue limestone	4″
9.	Red shale	3′ 10″
10.	Purple limestone	6″
11.	Calcareous, red shale with three thin bands of purple limestone	9′ 10″
12.	Red, crystalline limestone	1′
13.	Red shale	1′
14.	Red, crystalline limestone	1′
15.	Red shale	11′
16.	Blue limestone	3″
17.	Red shale	1′
18.	Blue limestone	2″
19.	Pink limestone	1′
20.	Red shale	4′ 4″
21.	Cherty, white limestone	4″
22.	Compact, red shale forming a cliff	8′
23.	Alternating layers of buff and red shale	13′ 6″
24.	Dense, purple, calcareous shale carrying bands of pink calcite and forming a cliff. Contains occasional thin bands of chert	9′ 6″
25.	Blue, calcareous shale with an onion-like concretionary structure on a large scale	5′
	Total	85′ 5″
c.	*White limestone.*	
1.	Thin-bedded, white, cherty limestone carrying the chert in parallel bands, and containing three paper-thin layers of purple shale. Weathers to a white powder. Dendritic markings are present	2′
2.	Nodular, white, cherty limestone. The chert is present in irregular nodules of no definite shape.	

	Character	Thickness
	The upper part of the stratum has a paper-thin bedding giving it the aspect of a calcareous shale. The limestone weathers to a white powder. Dendritic markings are present	2′
3.	Dense, homogeneous, white, crystalline limestone, forming a cliff. The upper part is thin-bedded	3′ 8″
4.	Homogeneous, thin-bedded, white, crystalline limestone containing occasional thin bands of chert and nodules whose character suggest the structure of Cryptozoön	8′ 6″
5.	White limestone carrying a large amount of chert in undulatory and gnarled bands	2′ 4″
6.	Lumpy and gnarly, white limestone carrying chert in large irregular nodules. Crumbles to a white powder	2′ 6″
7.	Purple shale	
8.	Layers of undulatory-banded, bluish chert	1′ 10″
9.	Soft, purple shale	5″
10.	Layer of gnarled and twisted chert nodules in a matrix of white talc. The surface of the talc is covered with dendritic markings	2′
11.	Thin-bedded, white limestone crumbling to white powder or weathering into thin plates like a shale	2′
12.	Soft, purple shale	1′
13.	Thin-bedded, crystalline, white limestone	3′ 10″
14.	Soft, purple shale	1′ 10″
15.	Dense, blue, crystalline limestone forming a small cliff	3′
16.	Homogeneous, thin-bedded, white limestone, crumbling to a white powder and weathering into plates like a shale	15′
17.	Dense, crystalline, blue limestone	4″
18.	Purple shale	3′ 3″
19.	Layers of undulatory-banded, nodular chert in a matrix of earthy white limestone	3′ 10″
20.	Thick-bedded layers of pure, homogeneous, white marble, forming the strongest cliff in the second member of the Unkar	6′ 8″
21.	Same in thinner beds	6′ 6″
22.	Undulatory-banded, cherty limestone becoming crystalline above	10′
23.	Red shale below and purple shale above, separated by a thin layer of chert	5′
24.	Thick-bedded, crystalline, white limestone of the same character as 20, forming a strong cliff	3′ 6″

CHARACTER	THICKNESS
25. Thin-bedded, crystalline, white limestone	5′ 6″
26. Gnarled and nodular, white, cherty limestone	7′
27. Very hard, dense layer of flint forming small cliff	5″
Total	105′ 2″
d. Blue slate and white limestone.	
1. Soft, purple shale	3′ 6″
2. Hard, blue slate forming small cliff	1′
3. Fissile, blue slates with fine partings	7′
4. Thin-bedded, purple, crystalline limestone	1′ 2″
5. Dense, purple, crystalline limestone forming a small cliff	7″
6. Same as 4	2′ 2″
7. Same as 5, forming small cliff	8″
8. Thin-lamellar, spotted, blue slate	6′ 6″
9. Gnarly layers of fine-lamellar, blue calcareous slate with a very coarse concretionary structure. Irregular nodules of chert occur in the middle portion	33′
10. Dense, blue, crystalline limestone forming small cliff	2′ 3″
11. Thin-bedded, platy, white limestone	2′ 6″
12. Very thin-lamellar, fissile, blue slate	3′
13. Calcareous, blue slate forming a cliff	3′
14. Thin-bedded, platy white limestone	4′ 6″
15. Fissile, blue slate	7′
16. Dense, lumpy, white crystalline limestone	2′
17. Pinkish-green, fissile, siliceous slate of a jaspery appearance forming a cliff	5′
18. Layers of dense, white, crystalline limestone separated by thin bands of pale-green, talcose material	10′
19. Dense, red and black-banded jasper, weathering green between the layers and forming a cliff. The layers contain shrinkage cracks and ripple marks	11′ 4″
20. Layers of dense, white, crystalline limestone separated by bands of pale green, talcose material	2′
Total	108′ 2″

Synopsis of second member of the Unkar.

a. Basal white limestone	6′
b. Argillaceous and calcareous red shale and limestone	85′ 5″
c. White limestone	105′ 2″
d. Blue slate and white limestone	108′ 2″
Total thickness	304′ 9″

When the specimens of these rocks were examined in the laboratory it was found that all the limestones were more or less dolomitic. The limestones of division "*c*" were found to be entirely dolomites.

Thin sections were cut from specimens from twenty separate beds in the second member. Eighteen of these slides were cut from the limestone strata and two from the red shales. The sections of the limestones were cut both from the chert bands and the nodules and from the limestone itself, for the purpose of ascertaining the exact mineralogical character of these rocks, and in the forlorn hope that they might reveal traces of a structure that could be referred to something organic. No minerals other than calcite and quartz were revealed by the microscope in any of the slides. The silica of the chert bands and nodules was found to exist in the form of interlocking grains of quartz. None of the grains were rounded and there was no suggestion that the quartz grains of the chert bands represented an inwashed sand. Nor was there any trace of an organic structure revealed, either in the chert or in the limestone. The purer limestones were found to consist of calcite (or dolomite) alone, the crystalline forms having the typical structure of marble. The impure varieties were found to consist of mixtures of quartz and calcite in all proportions. The greater part of the limestone was of this impure character. The shales were found to consist of a fine impalpable ferruginous or calcareous mud, containing occasionally a minute grain of quartz.

Several features of interest are shown in the lithologic section of the second member of the Unkar as a whole.

Ripple marks and sun cracks appear for the first time in the shales in stratum No. 18 of division "*d*," just below the highest limestone stratum at the summit of the member.

The increasing intensity of metamorphic phenomena in the section from the base upward may also be noted. This is due to the approaching proximity to the lower contact of the diabase sill which is intruded in the member above. The metamorphic action is manifested in the shales by their change upward both in color and in degree of induration: the shales of division "*b*" are almost entirely red; from the summit of this division upward the color changes to purple and blue. Below division "*d*" the shales are soft and crumbly; within this division, however, they become dark blue slates, while in the upper part they become extremely hard, siliceous jaspers.

The vertical succession of the strata is seen to be broadly characterized by continual and rapid alterations of limestone and shale. According to the dominance of either type of rock the four divisions *a*, *b*, *c*, and *d* are separated: division "*a*" is entirely limestone, "*b*" is alternating limestone, and "*d*" predominantly shale. Thus there are four major cycles of oscillation upon which the minor cycles are superimposed.

A comparison of the above section in the East Wash with a section measured in the Asbestos Canyon, four miles to the west, is of interest. In the Asbestos Canyon the "basal white limestone" (*a*) has a thickness of 30 feet contrasted with a thickness of 6 feet in the East Wash. The lower stratum of "nodular, cherty limestone" is there 7′ 9″, contrasted with 1′ 6″ in the East Wash. The upper stratum of "parallel-banded, cherty limestone" is 22′ 3″ in the Asbestos Canyon, containing in the middle an intercalated layer of purple shale, and near the top a thin layer of rather fine arkose conglomerate. The "argillaceous and calcareous red shales and limestones" of division "*b*" have a thickness of 88 feet in the Asbestos Canyon contrasted with 85′ 5″ in the East Wash. They do not have the red color that characterizes them in the East Wash, but are purple and blue, and much indurated. This change of color and difference in degree of induration is due to their closer proximity to the diabase sill in the Asbestos Canyon.

The correspondence in lithographical character and vertical succession of these two sections four miles apart is so close that the individual strata of the sections can be matched bed for bed. The only marked contrast in thickness occurs in the basal white limestone (*a*).

Third Member.—Argillaceous and Arenaceous Shale.

Section measured at East Wash in continuation of the preceding section.

a. Cliff-forming jasper.

1.	Dense, hard layer of blue-black jasper mottled with red spots and showing no banding in the mass, forming with the three following layers a strong perpendicular cliff. This is the most resistant rock in the Unkar. Where the under surface shows beneath the overhang of the cliff it is sun-cracked on a large scale and in several generations	28′
2.	Same general character as 1, but showing a banded structure. The lower 2 ft. are slaty and weather out, giving the cliff an overhang	19′
3.	Same as 2 with a soft slaty layer at the base	14′
4.	Same as 2 and 3 with a soft layer at the base.	12′
	Total	73′

b. *Calcareous blue slate.*

1. Slaty, black jasper, sun-cracked throughout	12′	
2. Pink, crystalline limestone	1′	6″
3. Slaty, blue jasper with small red spots	4′	6″
Total	18′	

c. *Cliff-forming jasper.*

1. Dense, hard layer of blue-black jasper mottled with red spots, forming with the following layer a strong cliff	14′	
2. Same as 1 with a soft slaty layer at the base which weathers out, giving the cliff an overhang.	3′	6″
Total	17′	6″

d. *Sandy quartzitic jasper.*

1. Slaty, blue, spotted jasper	4′
2. Fine-grained, pink quartzite, ripple-marked	5′
3. Slaty, blue, spotted jasper	12′
4. Fine-grained, pink quartzite	4′
5. Slaty, blue, spotted jasper with sun-cracks	6′
6. Fine-grained, pink quartzite, ripple-marked	1′
7. Pink, quartzitic jasper	5′
8. Fine-grained, pink quartzite	4′
9. Fine-grained, pink, sandy jasper, sun-cracked	11′
Total	52′

e. *Red and blue jasper.*

1. Banded, blue jasper with curious spots. Sun-cracked throughout	22′
2. Red and black banded jasper	9′
Total	31′

f. At this horizon is intruded a sill of diabase, whose thickness varies from 650 feet on the Shinumo to 950 feet or more in the Asbestos Canyon.

The remainder of the section was measured in a traverse up the Shinumo, starting with the upper contact of the diabase sill.

g. Blue slate and quartzite forming a cliff	20′
h. Blue slate forming a slope	100′
i. Red, argillaceous shale — sun-cracked throughout. The rock is very soft and forms a slope together with the underlying blue slate	91′
j. Alternating, vermilion, argillaceous shale and sandstone.	

The alternations in this series occur with remarkable regularity. The sandstone is white in color and is compact and fine-grained. It is cross-bedded and ripple-marked throughout. The shales of the alternating beds are very soft and weather out, leaving etched-out bands between the sandstones which are very conspicuous in the cliff-faces. On the undersurface of each sandstone layer are beautifully preserved sun-cracks. The shales are fine-grained, fissile, and argillaceous.

The succession in this alternating series is as follows:

No.	Bed	Thickness	S. S.—Sh. cycle
1.	Sandstone	4′ 2″	
2.	Shale	3′10″	8′
3.	S. S.	2′	
4.	Sh.	3′	5′
5.	S. S.	1′	
6.	Sh.	2′	3′
7.	S. S.	7′	
8.	Sh.	10′ 6″	17′ 6″
9.	S. S.	5′	
10.	Sh.	3′	8′
11.	S. S.	6′	
12.	Sh.	2′ 6″	8′ 6″
13.	S. S.	6′	
14.	Sh.	3′ 6″	9′ 6″
15.	S. S.	6′	
16.	Sh.	3′ 6″	9′ 6″
17.	S. S.	7′ 6″	
18.	Sh.	4′	11′ 6″
19.	S. S.	3′ 6″	
20.	Sh.	6″	4′
21.	S. S.	2′	
22.	Sh.	1′	3′
23.	S. S.	3′10″	
24.	Sh.	2′ 6″	6′ 4″
25.	S. S.	2′	
26.	Sh.	6′ 6″	8′ 6″
27.	S. S.	3′	
28.	Sh.	4′	7′
	Total,	109′ 4″	Ave., 7′10″

k. Alternating, vermilion, arenaceous shale and sandstone.

The sandstone is white, compact, and fine-grained. It is cross-bedded and ripple-marked throughout. The undersurface of each sandstone layer is sun-cracked where it rests upon the arenaceous shale. The shale is vermilion in color, soft, and very sandy. Sun-cracks occur throughout.

The succession is as follows:

1. Sandstone	9′ 4
2. Arenaceous shale	21′ 1″
3. Sandstone	9′
4. Arenaceous shale	11′ 8″
5. Sandstone	2′
6. Arenaceous shale	24′
7. Sandstone	1′
Total	78′ 1″

Synopsis of third member of the Unkar.

a. Cliff-forming jasper	73′
b. Blue slate with calcareous band	18′
c. Cliff-forming jasper	17′ 6″
d. Sandy quartzitic jasper	52′
e. Red and blue jasper	31′
f. (Intrusive diabase)	
g. Blue slate and quartzite	20′
h. Blue slate	100′
i. Red argillaceous shale	81′
j. Alternating vermilion argillaceous shale and S. S.	109′ 4″
k. Alternating vermilion arenaceous shale and S. S.	78′ 1″
Total thickness	579′11″

Thin sections were cut from several specimens of the jaspers. The slides were unsatisfactory, however, because of the exceedingly fine grain of the rock. The highest power of the microscope revealed nothing more than an impalpable silicified mud. A slide of the "quartzitic jasper" showed it to have been a somewhat arkose sandstone indurated to a siliceous quartzite. It was seen to be composed chiefly of small rounded quartz grains about which secondary silica had been deposited, lying in a fine arkose matrix made up of small fragments of pink feldspar. A thin section was also made from a specimen of one of the sandstone layers in the "alternating argillaceous shale and sandstone" of division "*j.*" The rock proved to consist of small, well-rounded grains of quartz, cemented by silica in the form of secondary quartz. It is a pure, fine-grained sandstone.

The metamorphic effects produced by the diabase sill intruded at the horizon "*f*" are seen in the lithologic section of the third member given above. This metamorphic action is manifested in three ways:

1. Induration by silicification,—jaspers.
2. Induration by baking,—slates.
3. Decoloration,—red to blue and black.

It was noted in the summary of the features of the second member that the shales became successively slates and jaspers above, while their color changed from red to blue. In the third member the shales are represented entirely by jaspers and quartzites. Just below the contact the induration is very great, and the jaspers are tough and vitreous; the prevailing color is blue or black. Above the contact the overlying rocks are hard blue slates for 20 feet, succeeded by 100 feet of less indurated slate, grading upward into the original red shale.

The metamorphic effects above and below the contact differ in degree of intensity as well as in kind: above the contact the induration and decoloration characterize only about 100 feet of strata; below the contact this action extends through 300 feet. Above the contact the strata are characterized by baking and decoloration only, changing the red shale into a blue slate; below the contact there has been a considerable addition of silica, transforming the red shales into blue and black jaspers; added to this are the effects of baking and decoloration.

It may be said in summary that the third member is characterized by argillaceous shales in the lower portion, which grade upward into arenaceous shales and sandstones through the interesting series of alternations described in division "*j*." There is hardly a stratum in the entire member that does not bear marks of shallow water origin, manifested by either suncracks, ripple-marks, or cross-bedding.

Fourth Member.—Sandstone and Quartzite.

Section on the Shinumo.

a. Purple-brown sandstone of fine grain containing locally an occasional lense of fine conglomerate and sometimes a thin local bed of red or purple shale. The sandstone is cross-bedded throughout	406′
b. Compact, white quartzite of fine and uniform grain, displaying a faint cross-bedded structure. This quartzite is the most resistant rock in the fourth member. It is exposed everywhere in one massive perpendicular cliff face, which does not display the slightest break except where it is cut by faults. Wherever its base rests upon a shaly lense the under surface displays well preserved mud-cracks. The face of the cliff is stained magenta by the ferruginous cement of the shale lenses in the overlying sandstones, which washes down from above	119′
c. Purple-brown sandstone of the same character as *a*	353′
d. Banded, white quartzite, stained magenta on the exposures, and forming a cliff	120′

e.	Fine-grained, purple sandstone with a white band in the middle. The white band is constant and presents a conspicuous feature by which this purple sandstone can be distinguished at a distance of several miles. The rock is cross-bedded and sometimes displays a "twisted and gnarled" structure	150′
f.	Compact, cliff-forming, white quartzite of the same character as *b*, though not so massive in structure	250′
g.	Banded white quartzite	20′
h.	Irregularly bedded sandstone	
	1. "Curiously twisted and gnarled layers," of fine-grained white sandstone containing large red spots of a circular and elliptical form. The upper part of the bed is more massive. The twisted and gnarled structure seems to have been a phenomenon of the original deposition. It gives the rock an appearance which suggests that the original sand was moist and plastic and once flowed by rolling over and over in the form of a quicksand.	105′
	(It may be noted that a bed of this character is described by Walcott in his section in Unkar Valley. (Walcott *b*, page 511.) It occurs at the same horizon as the bed described above, and contains the same red spots.)	
	2. Banded, purple sandstones	20′
	3. Green, cross-bedded sandstone	21′
		146′

The total thickness of the fourth member of the Unkar is 1564 feet.

Slides were cut from several specimens of the sandstones and quartzites. All were found to consist of small rounded quartz grains, the size of which seldom exceeds $0{\cdot}7^{mm}$. This extreme fineness and roundness of the grains, as well as the cleanness of the sorting, is remarkable. The cement is usually siliceous, sometimes slightly ferruginous. A slide was made from a specimen taken from one of the small conglomerate lenses in division *a*. The conglomerate was found to consist of small rounded quartz pebbles, lying in a fine arkose matrix. Occasional large angular fragments of orthoclase and microcline were revealed.

In summary it may be said that the fourth member is characterized by great thicknesses of pure, fine-grained sandstone of a uniform character. All divisions of the member are resistant to the weather and form cliffs. Ripple marks and cross-bedding occur throughout.

Fifth Member.—Micaceous Shaly Sandstone.

Section measured in Fault Wash, west side of Shinumo Canyon.

a. Gray-green, pinkish-green, and brown micaceous shaly sandstones, cross-bedded and ripple-marked, varying in character only through gradations in color. Frequent arenaceous and argillaceous shaly partings occur, causing the rock to weather like a soft sandy shale. The shale partings are usually green. Some of the sandy layers near the base show the "gnarled and twisted structure."	1100′
b. The green, gray, and brown beds of *a* pass upward through change of color into red and vermilion beds of the same general character. These are likewise micaceous shaly sandstones, cross-bedded and ripple-marked, with arenaceous and argillaceous shaly partings, which display well preserved mud-cracks. The shaly partings are either green or red	1197′
Total	2297′

The summit of the Unkar section is obliterated in the beds of division *b* by the plane of the pre-Tonto unconformity. The highest beds of this division lie at the upper end of the Fault Wash, dragged against the Vishnu schist on the north by the great pre-Cambrian fault previously described, and the whole overlain by the Tonto sandstone.

In the uppermost part of division *b* are four thin sills of rotten basaltic rock, weathering green and crumbling to small fragments. They occur between the beds of vermilion sandstone and shale. Their intrusive character is shown by the fact that they have baked and decolorized the vermilion beds for a few inches both above and below the contacts, changing the color to purple. The rock is too badly weathered to allow a petrographic determination in thin section.

In summary the fifth member of the Unkar may be characterized as a series of micaceous shaly sandstones of uniform character, varying only in color, and bearing marks of shallow water origin throughout.

Comparison with the type section in Unkar Valley.—A comparison of the above section of the Unkar group with that described by Walcott (*d*) in the type locality 30 miles to the east reveals the fact that the correspondence between the two sections is very close, both in thickness and in lithological succession; only in the lower portions do they differ materially. The type section in Unkar valley is characterized by a greater thickness of the basal conglomerate, and by only a third as much limestone in the members which correspond to the second member on the Shinumo; the deficiency in limestone is made up by greater thickness of arenaceous and argillaceous shale. Proceeding upward in the section there is a somewhat greater proportion of sand in that division of Walcott's section which corresponds to the third member on the Shinumo. The succeeding members correspond closely in character and thickness even to the minor divisions; an example of this is the "gnarled and twisted layers" previously cited.

The writer had the privilege of examining Mr. Walcott's field specimens in the National Museum in Washington and was particularly impressed by their absolute lithological identity with the series collected by himself from corresponding horizons on the Shinumo. The two series of specimens, with the exception of those rocks altered by local metamorphic phenomena, might have come from the same locality.

DIABASE INTRUSIVE IN THE UNKAR.

Occurrence.—The diabase occurs in the form of an intrusive sheet or sill which occupies three separate stratigraphic horizons in the Unkar sediments in different parts of the Shinumo area. On the west side of the Asbestos Canyon three miles west of the Shinumo it is intrusive in the limestones of division *c* of the second member of the Unkar at a horizon 15 feet above their base. On the east side of the Asbestos Canyon it ascends out of this horizon and breaks across the overlying limestones and shales in an eruptive contact. Most of the lower, and part of the upper, sections of the eruptive contact are beautifully displayed in the walls of this canyon, but the complete exposure is obliterated above by the truncating unconformity at the base of the Tonto sandstone. Between the exposures in the Asbestos Canyon and the main areal exposures about the mouth of the Shinumo, the pre-Cambrian structure is hidden beneath the sandstone of the Tonto platform. Where the diabase reappears in the exposures about the Shinumo it is found to lie intruded midway within the shales of the third member of the Unkar at a horizon 400 feet above that which it occupies in the Asbestos Canyon. This is the stratigraphic position which it holds in all the exposures of the central part of the Shinumo area. Eastward up the river from the East Wash the diabase again disappears beneath the pre-Tonto unconformity. But directly under Havasupai Point, about three miles farther east, limited outcrops of the basal portion are exposed in small inter-canyon valleys on both sides of the river. Here the lower contact of the diabase lies just at the top of the "white limestones" of division *c* of the second member of the Unkar.

The thickness of the sill is approximately 650 feet on the Shinumo and 950 feet on the west side of the Asbestos Canyon. Eastward from the Shinumo the outcrop is considerably thinned by a strike fault, precluding the possibility of measuring the thickness in that direction.

PETROGRAPHY.

Megascopic.—The fresh specimens characteristic of the greater part of the mass show it to be a tough, heavy, holocrystalline rock of medium to coarse grain and of a grey color. The minerals visible to the unaided eye are plagioclase, olivine, augite, and an occasional grain of magnetite. Although the olivine exceeds the augite in amount, it is less conspicuous to the eye. Aside from a somewhat waxy luster of the feldspars, the rock is remarkably fresh. The weathered surface has a characteristic warty appearance, imparted by the presence of lumps or balls which are of a coarser grain and different texture than that of the mass of the rock and are more resistant to the processes of disintegration. These lumps and balls can be seen to consist of coarse ophitic intergrowths of augite and plagioclase. The diabase weathers by mechanical disintegration to a greenish-olive sand in which are innumerable lumpy kernels of all sizes derived from the ophitic masses described above. The rock has no typical columnar structure, but usually displays a rough vertical jointing such as is characteristic of granite.

Microscopic.—The slides examined show the typical rock to consist primarily of plagioclase feldspar (near labradorite) and olivine in about equal amounts, with a subordinate quantity of augite and brown biotite. A very little magnetite is present. The feldspar is somewhat altered, but all the other minerals are fresh. The olivine occurs characteristically in rather large, rounded crystals of automorphic habit. The augite is chiefly confined to the globular masses which weather out as lumps and kernels and does not characterize the rock as a whole. Slides cut from these kernels show them to be composed entirely of augite and feldspar. The augite is enclosed within the feldspar, displaying beautiful examples of ophitic texture. Several of the magnetite crystals were observed to have rims of brown biotite. The small amount of magnetite is rather remarkable, and it seems likely on this account that the olivine is rich in magnesia. Because of the predominance of olivine and plagioclase in the greater part of the rock, the diabase is classified as an olivine-diabase with a troctolitic aspect.

Variations in character.—All parts of the mass are subject to variations in texture and composition toward a coarser grain. These are of two kinds. The first type occurs in the ophitic intergrowths of augite and plagioclase in the lumps and balls described above, and is a segregation phenomenon characterizing the mass as a whole; sometimes this texture becomes very coarse, the separate crystals of augite or plagioclase attaining an inch in length. The second type occurs in typical pegmatite dikes cutting the diabase in many places and varying in width from a few inches to several feet. The minerals are plagioclase and augite and the texture is usually ophitic, although not always so. In some of these dikes crystals of plagioclase exceeding three inches in length were observed.

The contact facies of the diabase are frequently fine-grained or glassy, but never for more than a few inches from the contact. The slides typical of this zone reveal a hyalopilitic arrangement of glass with skeleton crystals of magnetite between badly altered crystals of feldspar.

For about a half-mile east and west of the Shinumo there occurs in the upper part of the diabase sill along the upper contact a pink holocrystalline rock of medium grain. The contact of this rock with the overlying blue slates is sharp and well-defined. Downward it appears to grade into the normal diabase, and no definite line of contact can anywhere be observed. Unfortunately the writer did not collect transition specimens, but took only one specimen from the middle of the pink mass. The slide from this specimen when examined under the microscope showed it to be a granular rock of medium texture, consisting of rather fresh crystals of orthoclase, with subordinate quartz and a somewhat altered ferromagnesian mineral which was made out to have been originally a hornblende. Some of the quartz displayed a micrographic arrangement within the feldspar. The rock is a typical hornblende-syenite, and is apparently an interesting example of differentiation in place within the diabase sill. But a more complete set of specimens across the apparent transition zone must be collected before such a conclusion can definitely be established.

In the Asbestos Canyon both the lower and upper eruptive contacts of the diabase are ragged and considerably injected. Many small dikes penetrate the country rock from the main mass. They are glassy in texture and badly altered.

Ransome, in his report upon the "Geology of the Globe Copper District, Arizona" (Ransome *b*, p. 80 ff.) describes a diabase of post-Carboniferous age occurring in thick sills in the pre-Carboniferous sedimentary rocks of that region. This diabase closely resembles the Algonkian diabase described above, both in mineralogical character and in the presence of the ophitic balls of plagioclase and augite. The analogy is made the more striking by the fact that several small masses of pink hornblende-syenite are described occurring within the diabase sills of the Globe district as a possible segregation phenomenon within the diabasic magma.

Contact metamorphism.—Since the diabase sill occupies relatively different horizons in the Unkar strata upon the Shinumo and in the Asbestos Canyon, and since in the former locality the strata between which the sill is intruded lie in undisturbed sedimentary contact in the latter locality, and vice versa, the study of the respective contact effects upon the invaded strata could be made with great facility.

The contact effect upon the shales which lie above and below the diabase along the Shinumo has already been described in the detailed section of the Unkar: there the shales were shown to be altered to jaspers by baking and silicification. It was shown that the intensity of metamorphic action was much greater below the sill than above, extending through 300 feet of strata below the lower contact and through only 100 feet above the upper contact. In the Asbestos Canyon these rocks lie in undisturbed sedimentary contact and are there unaltered red shales.

The contact effect upon the limestones can be studied in the Asbestos Canyon, where the diabase sill lies intruded within them. Immediately below the lower contact of the diabase, which is sharp and well defined, is a thin layer of green serpentine. Below lie layers of pure crystalline limestone (dolomite) alternating with layers of the same character containing bands and nodules of serpentine. Within one of the layers containing the bands and nodules of serpentine are cross-fiber veins of golden-yellow chrysotile asbestos which are parallel in general trend to the bedding of the limestone. These limestones are the layers at the base of division *c* of the second member of the Unkar. They overlie the red shales of division *b*, which are here baked to blue slates.

Section below diabase contact (reading upward from the base)

Dense, purple, calcareous slate (*b*, 24 of second member of Unkar)	9′
Soft, blue slate (*b*, 25)	3′
Nodular, cherty limestone (*c*, 1, 2)	4′
Banded, crystalline limestone with bands and nodules of serpentine (*c*, 3, 4,)	10′
Serpentinous, nodular and banded layer carrying veins of asbestos	1′
White, crystalline limestone with bands and nodules of serpentine	2′
Pure, white, crystalline limestone	1′ 6″
Layer of green serpentine	2′
Diabase.	

Above the upper contact of the diabase the limestones contain several alternating layers of green serpentine and narrow veins of asbestos occur at several horizons in proximity to the contact.

The geological occurrence of the asbestos is fully described by Diller in "Mineral Resources of the U. S. for 1907" (Diller, *a*), and again by the same writer in "Mineral Resources for 1908" (Diller, *b*). The contribution of the writer of the present article consists of the further data afforded by a microscopic study of the rocks associated with the asbestos in this locality. A microscopic study was made of 25 thin sections cut from the limestones, the bands and nodules of serpentine, and across the veins of asbestos. Aside from the serpentine and asbestos no other minerals were revealed in the limestones beyond the dolomitic calcite and interlocking grains of quartz already described in the slides cut from the limestones of the same horizon in the section on the East Wash, where the same strata lie in undisturbed sedimentary contact. The texture of the limestones is entirely that of marble. The serpentine of the bands and nodules shows no trace of an alteration structure which might indicate a derivation from pyroxene, hornblende, or olivine. The slides cut across the veins of asbestos showed them to be later than the serpentine in which they are usually enclosed. A great number of veins of asbestos of microscopic size was revealed in some of the slides where their presence was unsuspected. Some of these veins were observed cutting across both the serpentine and the limestone in the same slide.

The asbestos which occurs in the larger veins is commercially of high grade and the fiber is of great tensile strength. It is pronounced by Diller to be the best in quality yet found anywhere in the United States. (Diller, *b*, p. 11.) Locally the crossfiber is 4 inches in length. The horizon of the larger veins is confined, so far as is known, to the limestones which lie beneath the lower contact of the diabase sill. The veins above the contact, although more widely distributed through the limestones, are usually of smaller size. The horizon below the contact is not absolutely constant in stratigraphic position and may lie anywhere from 3 to 15 feet below the contact. The width of the veins within this horizon varies greatly from place to place, so that a vein of three inches in width in one locality may be represented by a zone of innumerable small veins in another, but the actual continuity of the zone that carries the asbestos is rarely broken.

Conclusions.—The serpentine and asbestos occur in the limestones only where these strata are invaded by the diabase sill; where the diabase lies between shales there is no development of these minerals within the invaded strata. In no place in the area are they developed within the diabase itself. It is therefore clear that they are a contact metamorphic phenomenon conditioned by the invasion of the limestones by the diabase. It seens probable, as suggested by Diller (*a*, p. 72), that the serpentine which encloses the veins of asbestos is derived from some mineral in the limestones and not from the diabase. The limestones themselves are magnesian, and locally siliceous in the form of chert bands and nodules. In another part of the area the conversion of the shales to jaspers where they are in contact with the diabase is evidence that the fumarolic action accompanying the injection of diabasic magma was manifested by aqueous and probably siliceous emanations and was fairly intense. It seems possible that the operation of the fumarolic action upon the elements already present in the magnesian limestones might have been sufficient to convert the more siliceous portions into serpentine. The occurrence of the asbestos in veins that cut both the nodules of serpentine and the limestones is evidence that the formation of the cross-fiber asbestos was itself a somewhat later phenomenon.

Age and Correlation.

The Grand Canyon series is referred to the Algonkian in the usage of the United States Geological Survey and is tentatively correlated with the Keweenawan series of the Lake Superior region and with the Llano series of Texas, following the conclusions established by Walcott (*b*, p. 518). In the Shinumo area the profound nature of the unconformity which separates these strata from the basal Tonto sandstone is even more striking than in the area described by Walcott, while the certainty of their stratigraphic position is in its clearness and spectacular character probably unparalleled in the world.

GEOLOGIC HISTORY.

Outline.

The following sequence of events may be distinguished:

1. Deposition of the Vishnu sediments, source unknown.
2. Regional metamorphism.
    - *a.* Subsidence and profound burial.
    - *b.* Orographic movement of folding and compression resulting in recrystallization and schistosity, accompanied or preceded by injections of pegmatite.
    - *c.* Elevation, accompanying or succeeding the orographic movement.
3. Batholithic invasion of quartz diorite.
4. Later pegmatitic injections.
5. Long cycle of erosion carried through to a featureless peneplain of no relief, which truncates the very roots of the Vishnu structure.

6. Sudden incoming of the shallow Unkar sea.
7. Deposition of the Unkar sediments and succeeding strata of the Grand Canyon series in shallow water (or upon land ?)
8. Intrusion of diabase sills.
9. Orographic movement of block faulting and tilting accompanied or succeeded by elevation.
10. Long cycle of erosion carried through to a peneplained surface of small relief.
11. Incoming of the Tonto sea, succeeded by the deposition of the Paleozoic strata of the wall of the Grand Canyon.

The earliest event which is decipherable in the geologic history of the Shinumo area is found in the blurred and mangled record of the Vishnu schists. Far back in the dark ages of geologic time a thick series of more or less arkose sands and muds was accumulating upon a subsiding floor. So much may be reasonably inferred from the mineralogical character of the quartz schists of the mica and hornblende type. So dim and vague is the record that the base of this series, the floor upon which it was laid down, the thickness, and the location of the land mass from which it was derived must, perhaps, remain forever unknown. Following the long accumulation and burial of these sediments came an orographic movement which wrote across the older manuscript in a newer and bolder hand, blurring the ancient writing with the stamp of deep-seated regional metamorphism, and imparting to the manuscript the aspect of a palimpsest. The regional metamorphism is conceived to have been brought about by deep burial of the sediments, followed by folding and compression, which engraved upon them the characters of recrystallization and schistosity in slow process of time, and accompanied by their elevation into lofty mountains. Somewhat later the cores of these mountains were intruded by great masses of igneous rock, here in the form of quartz diorite, followed by pegmatitic injections. Perhaps while this orographic movement was still in progress the forces of erosion were already at work. Then followed a tremendous cycle of erosion carried through to the very end, planing away the ancient mountains to the basal roots, and reducing hard and soft rocks alike to an utterly flat and monotonous level. Such was the completion of the cycle of this vast unknown and unnamed æon of time.

The next event is the beginning of another great cycle of sedimentation resulting in the deposition of the Grand Canyon series of Unkar and Chuar strata, ushered in by the sudden invasion of a shallow sea which swept over the featureless desert surface of the Vishnu plain, depositing the basal conglomerate of the Unkar. The clue to the inferences as to the character of this incoming sea, of the rock mantle which it found covering the plain, and of the climate of the time is preserved for us in the basal conglomerate described in a previous part of this article. It was there noted that the weathering below the surface of the peneplain was slight, and the product of physical disintegration rather than of chemical weathering; that the matrix of the conglomerate is red in color and arkose in nature; that the pebbles are angular and show no evidence of transportation and sorting. We may therefore conclude that the conglomerate represents the soil in place which covered the Vishnu plain. All the evidence points to an arid climate,—the lack of chemical weathering, the freshness of the arkose feldspar, and the red color of the matrix, all indicating a lack of vegetation and abundant moisture which could decompose the soil and reduce the iron which imparts the red color. It is therefore not unlikely that the Vishnu plain was a vast desert at the incoming of the sea. The absolute lack of transportation, sorting, and rounding of pebbles indicates that the incoming sea had little chance to rework the soil mantle by its waves. It seems impossible to account for this phenomenon except by a sudden invasion of the sea across the Vishnu desert. If we interpret the past in the light of the present our only guide is to seek to picture some present condition on the earth which parallels that preserved in the geological record. A possible clue may lie in the conditions about the Caspian Sea to-day. There is in that region a desert about the shores of the Caspian which lies below the present level of the Black Sea; a sudden rise in the level of the ocean might cause the latter to overflow the low barrier which separates it from the Caspian, and in this way a sudden inundation of the desert would be accomplished. It is now thought that wind erosion may carry the surface of an old desert to a level below that of the sea if the cycle is continued to extreme maturity. Such forces might have been active in the last stages of the Vishnu peneplain.

The deposition of the alternating limestones and shales of the second member of the Unkar seems to have taken place in a permanent water body into which mud was frequently washed. It may be noticed from the section of this member that the alternations are almost innumerable. The exact cause of this is speculative. Possibly the alternations are due to climatic oscillation: a movement from an arid to a semi-arid climate would load the rivers with sediment, while arid intervals would retard their flow, if not dry them up entirely, resulting in a temporary clarifying of the sea and a deposition of limestone. Whether the limestones are the result of organic agencies or of purely chemical precipitation is also a matter of speculation, since in regard to decisive evidences of life the geological record is silent. It is believed that the water body was for the most part shallow, since sun-cracks appear in the shales in the upper part of the member below the highest limestone strata. What the polygonal cracks and the small cubic depressions in the banded cherty layers of the basal limestones mean the writer does not know. The cracks are suggestive of sun-cracks and the depressions strongly resemble salt hoppers.

The most striking feature of the third member is the great abundance of sun-cracks throughout the shaly strata and of ripple-marks and of cross-bedding in the sandstones. The researches of Professor Barrell have made it clear that extensive sun-cracking is a feature which has a maximum chance of preserval on broad flood plains or deltas in an arid climate. (Barrell, *a*, pp. 524–568.) In the opinion of the writer of the present paper, the extreme abundance of these cracks in this member of the Unkar is hard to account for except by postulating wide delta flats or flood plains. Furthermore, the bright red color of the shaly strata in connection with the mud cracks seems to bespeak an arid climate with little or no vegetation to reduce the iron. It is at least certain that all this part of the Unkar was deposited in very shallow water which often evaporated entirely, leaving broad mud flats exposed to a hot sun. In the upper part of the member is the series of alternating shales and sandstones already described in detail: as may be seen from the sections, the alternations are frequently as regular as clockwork. The sandstone layers are composed of fine, cleanly sorted and rounded quartz grains, ripple-marked and cross-bedded, while the shales are a fine red mud. It is thought that the clean character of the sandstone layers of this alternating series is a mark of climatic oscillation: a climatic movement towards a wetter climate, if increasing the ratio of run-off to erosion, causes the rivers to flow on a lower grade and sweep seaward the piedmont deposits of sand and gravel; as the clay was largely sorted from those deposits when they were first laid down, their redistribution accompanied by a secondary sorting on a delta surface or sea-bottom would be marked by extreme cleanness.

Great thickness, clear sorting, and extreme fineness and roundness of grain are the characters which distinguish the fourth member, which is composed entirely of sandstones and quartzites. All strata are characterized by cross-bedding and ripple-marks, bespeaking shallow water. The origin of these great thicknesses of sandstone is a puzzle. The clean sorting seems to indicate long transportation: it is not impossible that the rivers carrying this material might have flowed through a great desert of dune sands, picking up and carrying material such as is deposited in the Indus delta to-day from a similar source. Occasional lenses of fine conglomerate within some of the strata suggest scoured and filled stream channels.

The upper member of the Unkar again bears all the marks of shallow water origin: mud-cracks, ripple-marks, and cross-bedding characterize the entire thickness. The addition of micaceous material and of some feldspar gives a slightly arkose character to the rock; possibly a crustal movement rejuvenating the land mass supplying the sediments was responsible for the change in character. Here again are marks of aridity, seen in the vermilion color and the vast development of mud-cracks.

All subsequent Unkar and Chuar deposits have been removed by the truncation of the pre-Cambrian structure by the plane of the base-leveled surface of erosion beneath the Tonto Sandstone.

In summary it may be said that the evidence obtainable from the lithologic record of the Unkar sediments in the Shinumo Area points probably to an arid climate, and almost surely to deposition in shallow waters; first in a permanent body of water and later in deltas or on flood plains. Which of the latter conditions prevailed the writer is not competent to say.

The predominance of clastic sediments instead of limestones in the basal portion of Walcott's section, 30 miles east, suggests that that area was nearer to the shore line of the early shallow sea. The close correspondence of the stratigraphic succession and lithology in all higher members in the two areas suggests uniform conditions over at least that distance.

The next event which can be read from the geologic record is the invasion of the Unkar strata by a thick sill of diabase in the lower members, and by four thin sills of basaltic rock in the upper part of the section.

Following this came an orographic movement of block faulting and tilting, accompanied or succeeded by elevation, breaking the strata of the Grand Canyon series into great crustal blocks, and throwing them into high ranges of mountains which in character and aspect were probably not unlike the faulted ranges of the Great Basin or the desert ranges of Arizona.

Then began a second vast interval of erosion, gnawing slowly but surely into these faulted mountains, reducing them in slow process of time through stages of youth, maturity, and old age, and finally planing away all except the very hardest strata of their cores to form the broad monotonous expanse of a base-leveled surface. The monotony of this surface was broken only by an occasional monadnock of hard Unkar quartzite, resisting the forces of erosion in that ancient plain by virtue of the terrific hardness which causes the same strata to-day to wall in the deep box-canyon of the Shinumo. These monadnocks of the Cambrian plain may be compared with the Baraboo ridges of Huronian quartzite which by virtue of their homogeneity and hardness still stand as prominences which have weathered repeated cycles of erosion. It is probable that this cycle of erosion was not finally completed until well along in lower Cambrian time.

The next event is the incoming of the Tonto sea. Although this chapter belongs to the Paleozoic history recorded in the horizontal strata of the walls of the Grand Canyon, that part which is involved with the distribution of the Unkar strata upon the pre-Tonto surface may properly be anticipated here.

It is not unlikely that this invading sea transgressed a surface which strongly resembled the present surface of the great Laurentian peneplain of Canada with its broad areas of crystalline rocks in which are inset occasional blocks of Paleozoic strata, and above which stand occasional monadnocks of quartzite. The story of the invading sea is written in the Tonto Sandstone, locked up in which is a record of marine transgression which on account of the vertical sections and absence of soil is clear beyond belief. When the Tonto sea came in over the surface of the ancient peneplain the monadnocks stood out as islands which were gradually overwhelmed and buried in the sands of the deepening sea. The long ridge of the quartzites of the middle Unkar in the Shinumo area has already been described. It stood out as a long narrow rocky island whose longer axis extended for an unknown distance northwestward along the strike of the strata. The long southwest face of this island was undercut by the marine planation to form a steep cliff. Every detail of the face of this old sea cliff is preserved in the Tonto sandstone in the cross-sections cut by the present canyons across its face: at its base, huge angular blocks of Unkar quartzite as large as houses are preserved in the Tonto sandstone in the exact position where they fell and lodged; farther out from the base are masses of large bowlders, worn and rounded by the pounding of the waves; these become smaller and smaller and finally run out into lenses of fine pebbly conglomerate, representing the shingle of the ancient beach, dragged out by the undertow. No more striking example of a fossil sea cliff can be imagined.

By far the most impressive feature of this wonderful country is to traveller and geologist alike the mile-deep pathway of the Colorado River of the West across the great plateaus. The stupendous and glaring record of erosion revealed to us in the cutting of this mighty gorge has almost blinded us to the realization of the immensity of the vastly greater record revealed in its walls. But the story told by the two intersecting unconformities in the bottom of the gorge,—two ancient cycles of sedimentation, uplift, and erosion carried to a finish, separated by hopelessly lost intervals of time, resulting twice in the planing down of lofty mountain ranges to the very core, written vaguely at first on a blurred and time-worn record, and later in an increasingly clearer and bolder hand,—the slow accumulation of the strata of the Canyon wall on the floor of the Paleozoic sea, the subsequently erased record of the accumulation of vast thicknesses of Mesozoic and Eocene strata, separated in turn by great intervals of erosion, and even the "great denudation" which has stripped these later strata back fifty miles to the terraces of Utah—represents a lapse of time compared with which the cutting of the Grand Canyon is but the passing of an afternoon; for in the light of present knowledge it is safe to say that the Grand Canyon was entirely cut since the time when, according to the fossil record, the remains of man first appear on earth.

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Auburn, N. Y., January, 1910.

ART. XLV.—*On the Effects of Certain Magnetic and Gravitational Forces on the Motion of the Moon;* by ERNEST W. BROWN.

1. THERE exists a difference between the observed and computed places of the moon which has hitherto defied explanation. Its magnitude is so great in comparison with the accuracy obtainable both in theory and observation that it seems highly improbable that it should be due to error of any kind. From the observational side it has been known for over thirty years and during that time many efforts have been made, without success, to find its cause in the ordinary gravitational theory. It therefore seems pertinent to inquire whether some force or forces whose existence is only suspected may not be the cause of the discrepancy.

In setting forth the hypotheses mentioned below, my object is not at the outset to present a solution of the difficulty, and indeed no solution which can be accepted at the present time is offered. The reasons for the publication of the results of the investigation are of a different nature. The first is the consideration of certain forces whose constants are unknown but whose magnitudes can certainly be limited. It becomes possible in this way to exclude hypotheses which before actual computation do not appear to be highly improbable. The second object is to point out forces which are able to produce the inequality but which require to be confirmed by observations of a kind different from those obtained by the old methods of positional astronomy. And a third is for the purpose of indicating certain directions in which observations may be useful for the purpose of testing these hypotheses.

A possible magnetic attraction between the earth and the moon has occasionally been suggested, though its detailed consequences do not appear to have been worked out. The results below show that, although the magnitude of this attraction need not be very great, if it be a constant force its direction is unusual; or, if the magnitude of the force itself varies, the difficulty is only removed a step further back in that we know of no cause for such variation. The result arising from the figure of the sun demands conditions which may possibly be fulfilled but for which we must await further evidence. The supposed long-period term in the libration of the moon may in time be tested. For this purpose a long series of accurate observations would be necessary. In any case, such a series is needed in order to furnish more exact information than we at present possess of the motion of the moon about its center of mass, and this quite independently of any theory, gravitational or otherwise.

The mathematical developments by which the statements made below have been obtained are somewhat long and tedious. Since the results are either of a negative character or are obtained from hypotheses for which there is little or no collateral evidence, it seems unnecessary to develop at length the methods employed. When a disturbing function has once been obtained, it has now become a simple matter to compute rapidly the effect on the motion of the moon with the formulæ employed for the planetary terms, so that the details can be given at any time when the need for them may arise.

2. *The outstanding inequalities in the moon's motion.*—On several occasions during the past thirty years, Newcomb has examined the observations of the moon to try and find out what outstanding secular or long-period inequalities there may be in its motion which have not been explained by theory. Of these, the best known is the slow decrease in its period which increases its apparent longitude by 2″ multiplied by the square of the number of centuries from the epoch of reckoning. This is generally ascribed with good reason to tidal friction and it is not necessary to consider other causes of change except for the purpose of finding the amount of the frictional effect.

But Newcomb has also discovered a large change which appears to be periodic and which he deduced from observations of occultations of stars by the moon. His last paper* includes observations of this kind from the beginning of the seventeenth century, a range of nearly 300 years. The change appears to be periodic, with a coefficient of about 12″, a period of about 270 years and a phase which puts its maximum effect near the year 1795. Mr. P. H. Cowell makes the period about 350 years and the coefficient 18″ on the assumption that there is no secular change to be ascribed to tidal friction.† It is this long-period term for which no cause has as yet been assigned. There are also indications of a term with a period of about 60 years and a coefficient between 2″ and 3″; also a term with a period of some 20 years and a coefficient rather less than 1″. The last may possibly disappear when a comparison with the new tables of the moon's motion has been made and the arbitrary constants properly adjusted.

3. *Errors due to observation or theory.*—It is quite a simple matter to show that the peculiarities of observations on the moon cannot produce such a term. The majority of them are made at night and not very near new moon, and the moon itself has librations which alter its apparent diameter, but none of these can give rise to so large a term. There is the possibility of errors in Hansen's tables; but with the correc-

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* Monthly Notices R. A. S., vol. lxix, p. 164.

† Monthly Notices R. A. S., vol. lxv, p. 34.

tions now applied, it is extremely unlikely that further errors showing a periodicity of this kind are present.

The ordinary gravitational theory must at the outset be excluded. It has been so thoroughly investigated that there seems to be no likelihood of a term with so large a coefficient as 12″ having escaped detection. The term has frequently been ascribed to planetary action, but this action has now been treated in detail by several writers, and, in my own work on the subject, several thousands of terms were examined. Not the slightest possibility of the existence of a coefficient of anywhere near this magnitude has arisen. It may be noted that we are searching for a term nearly as great as the largest known term produced by planetary action, and further, that the next largest term has a coefficient only one-tenth of the required size. To ascribe the term to this cause would mean a defect in the theory so great that a total reconstruction would probably be necessary if an omission had been made.

4. *Method of investigation.*—The chief point is the period of the term, which is known from observation to be about 270 years. Now from the lunar theory we know that this period can be produced in three ways. It may be the effect of a nearly constant force on a term having this period, already present in the expressions for the moon's longitude. If the force be periodic, the period of the force must be either the period of the effect, or else the combination of the period of the force with one of the known periods in the moon's motion must produce the period of the effect. Now the period of the effect being 270 years, we must either look for a force having a period of 270 years, or else we must look for a force whose period differs from one of the lunar periods by a small quantity which runs through its changes in 270 years. The hypothesis of a nearly constant force is extremely improbable.

There is another point in the investigation that makes it easy to reject some of the hypotheses which may be brought forward. The mean annual motion of the perigee, as derived from theory and observation, shows no outstanding difference greater than 3/10 of a second; and a similar statement may be made with respect to the node. If, therefore, we assume the existence of some force which gives a motion to the perigee, or to the node, much greater than this amount, the hypothesis must be rejected.

5. In the examination of long-period terms in the moon's motion there is one point of great importance in the consideration of the magnitude of the disturbing force. If the force has a period near that of the month, this period not depending on the mean motion of the moon, the factor which is chiefly responsible for the large coefficient depends on the *square* of

the number of months contained in the period; but if the force has the same period as the effect, then the factor is only the first power of this number. With a period of 270 years, the factor is 3600, so it makes an essential difference whether the force is of long period or approximates to a month. If it approximates to the period of the perigee, or to that of the node, we still get the square of the factor, but there are small factors which enter and which may diminish the square of the large factor to some number between 10^5 and 10^6.

6. Certain forces may be rejected with but little calculation. Those which arise from a supposed resisting medium will give secular and periodic changes, the latter with periods the same as those of known terms in the moon's motion. Again, Jupiter has an ellipticity of about 1/17, and therefore might affect the motion of the moon. I have examined this and find that its effect on the moon is at most about 1/1300 of the principal effect produced by the planet. A small factor in the disturbing function reduces this very considerably. It is certain that the effect of Jupiter's ellipticity must be insensible. Further, there is a group of small planets lying between Jupiter and Mars which will undoubtedly have some influence on the moon's motion; but this influence, when calculated, is seen to affect chiefly the motions of the perigee and node. The resulting addition to these motions cannot be more than a few hundredths of a second per annum; otherwise the group would more seriously alter the motions of the inner planets than is possible, owing to the close agreement between theory and observation.

It may therefore be assumed that no gravitational action of the sun, earth, and planets, considered as particles, has been left out of account. Further, the figures of the earth and Jupiter, considered as spheroids, have been treated; the other planets are too small or too far away for their figures to have sensible influence. A possible non-spherical form of the sun will be treated in § 7. The constant term due to the figure of the moon has been taken into account, but an effect which would be caused by a certain kind of minute libration of the moon, if it existed, will be considered in § 9. Light pressure is also ineffective in producing a long-period term, and, indeed, any effect from it is too small to be detected within historic times.

7. *Hypothesis of an equatorial ellipticity of the sun's figure.*—Owing to its rotation, the figure of the sun is not a perfect sphere. There will be a slight difference between the equatorial and polar axes. This difference cannot, however, do more than alter the mean motions of the perigee and node by a minute amount.

The hypothesis under examination demands that the sun be not symmetrical with respect to every plane which passes through its axis of rotation, and further, that the period of rotation approximates closely to one of the lunar months. To justify the former we must suppose that the nucleus of the sun's mass is a solid body or behaves like one; otherwise it is improbable that an equatorial ellipticity could permanently subsist. A coincidence of the period of rotation with one of the lunar months is less difficult. Although the photosphere shows periods of rotation differing with different latitudes, it is probable that the nucleus of the sun's mass has a period of rotation like that of a solid body, and that the period is somewhere between the greatest and the least of those observed by watching the motions of sun-spots. Now this period, between 25 and 30 days, may possibly coincide very nearly with one of the lunar months. If it does so with a difference which is small enough, the effect on the moon's motion will be an inequality of very long period, provided the sun has some equatorial ellipticity of figure. We have, therefore, to make two assumptions; one, that the period of rotation of the sun very nearly coincides with one of the lunar months, and second, that its moments of inertia about two axes lying in the equatorial plane of the sun are not equal. The computation of such an effect is somewhat troublesome, but it gives a perfectly definite result. If the period of the sun's rotation with respect to a line joining the earth and sun differs from the period of the synodic month by a small quantity, so that the two phases only coincide once in 270 years, it is only necessary to assume that the effective ellipticity* of the sun in its equatorial plane is about 1/46,000. If we assume that the near coincidence is with an anomalistic month, then the ellipticity must be about 1,220 to produce the required term. If the near coincidence is with a nodal month an ellipticity of 1/2200 is sufficient.

These minute values are mainly due to the presence of the factor 3600^2, explained in §5. The introduction of two new hypotheses in order to explain a single phenomenon is objectionable and therefore requires some examination into their probability. Although observation has not yet reached the degree of accuracy required to compare the periods, it will be advisable to examine the material in order to see how closely we can compare them.

The periods of the three months relative to a line joining the mean positions of the earth and sun are:

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* The effective ellipticity is here defined to be the ratio of the difference of the moments of inertia to the product of the mass of the sun and the square of the radius of its visible surface.

Synodic	month,	$27^{d}\cdot3317$,
Anomalistic	month,	$25^{d}\cdot6217$,
Nodal	month,	$25^{d}\cdot3254$,

and one of these is to differ from the sidereal period of rotation of the sun by about $0^{d}\cdot0038$, since the angles present in the disturbing function are double the differences, and the period of the empirical term is about 3600 months.

The nodal month is nearest to the values found for the mean solar rotation period by Carrington ($25^{d}\cdot38$) and Spoerer ($25^{d}\cdot23$) from observations of the motion of sun-spots. W. S. Adams,* observing the displacements of certain lines of the spectrum, obtains periods ranging from $24^{d}\cdot57$ at the equator to $35^{d}\cdot26$ in latitude 79°. He inclines to the view that the equatorial velocities give a period approximating more closely to the actual period than those of higher latitudes. The evidence so far obtained indicates a possibility that the true rotation period may be close to that of the nodal month relative to the earth's mean radius vector.

A coincidence with the nodal month involves an effective ellipticity of about 1/2200. This might be detected over a long series of observations if the visible surface of the sun were solid. It is extremely unlikely that such an ellipticity would persist as far as the photosphere, which ought on the average to be a level surface. An indirect method may, however, furnish evidence one way or the other. If the ellipticity exists, it is probable that the solar activity would be more marked in two sectors on opposite sides of the solar axis than in the other two sectors. The average period derived from observations of sun-spots or other evidence of abnormal activity would therefore furnish the material to be examined. It is significant that the nodal period lies between the results for the solar period obtained by Carrington and Spoerer. The hypothesis opens up a wide field of speculation and investigation as to its physical consequences, especially on the motion of the outer liquid or gaseous layers of the sun's mass. The belief that the eleven-year period is due to forces within the sun is perhaps less difficult with the hypothesis of such an inequality in the distribution of the mass of the nucleus.

8. *Hypothesis of a magnetic attraction between the earth and the moon.*—For the purposes of this section it will be sufficient to consider the magnetic fields of the earth and moon as equivalent to fields produced by straight solenoids symmetrical with respect to their respective centers of figure. The directions of these solenoids will, in the first instance, be taken arbitrarily, but the main results of the discussion depend on the directions which may be assigned to them.

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* Astrophysical Journal, March, 1909.

The chief reason that the effect of magnetic attraction may be capable of observation arises from the fact that the resultant force varies as the inverse fourth power of the distance, while gravitation varies as the inverse square. It is in this respect similar to the attraction produced by the ellipticity of the earth's figure, that is, by the difference between the moments of inertia about the polar and equatorial diameters of the earth. For this reason it will be useful to compare the magnitudes of the forces which must be invoked with that produced by the earth's figure. It is, however, to be remembered that the resolved part of the magnetic attraction in any direction differs from that of the earth's figure, mainly because the earth's magnetic axis is not the axis of figure.

The potential of the magnetic attraction may with sufficient approximation be expressed in the form $(u_0+u_1)/r^3$ where u_0 is a constant and u_1 consists of terms whose mean value for all time is zero, and r is the distance between the moon and earth. It is a simple matter to prove that a force due to a potential u_0/r^3 must have an accelerative effect on the moon less than $5 \cdot 10^{-9}$ of that produced by the earth's attraction on the whole mass of the moon. This fact is deduced from the well-known result that the motion of the perigee, as determined by observation and theory, is not in error by so much as one part in $5 \cdot 10^6$. Now the principal effect of the earth's ellipticity is 10^{-7} of that produced by the main attraction of the earth. Hence the effect of a term u_0/r^3, here supposed to be due to magnetic attraction, must be less than 1/20 of that of the earth's ellipticity. Further, if the inequality which we seek to explain is produced by a force of the same period as that of the inequality, this force, contained in u_1/r^3, will not be greater than 1/120 of that of the earth's ellipticity.

These facts give the first negative result, namely, that *the inequality we seek to explain cannot be produced solely by the secular motion of the magnetic axis of the earth.* This secular motion is known with an accuracy for the last 300 years which is sufficient to prove that if it produced the inequality, it would cause an addition to the mean motion of the lunar perigee much greater than the agreement between gravitational theory and observation permits. Such a hypothesis appeared not unreasonable at one time, since there was some reason to think that the period of the secular variation was about 600 years and this would produce an inequality in the motion of the moon of half the period of the change. The period of the secular change, if a real period exists, is now thought to be considerably longer than 600 years.

Next, suppose that the inequality is produced by a variation in position only of an assumed magnetic axis in the moon.

In an exactly similar manner, it is proved that *this axis cannot oscillate about a mean position coinciding with or near the moon's axis of rotation.* The only way in which the variation of *position* is effective is an oscillation about a mean position in the lunar equator. Further, if the oscillations are perpendicular to the equator they must be large (of the order of 20°). If the oscillations are within the equator, the product of the magnetic moment and the amplitude of the oscillation becomes a factor which can be determined from the observed coefficient of the inequality, but there is no information at hand to separate the two terms of the product, since a motion of the perigee is not produced to this order of magnitude.

Let us next suppose that the directions of the magnetic axes are fixed with respect to the axes of figure of the two bodies, and that the inequality is produced by a variation of the product of the magnetic moments. Then, owing to the facts previously mentioned concerning the possible magnitudes of the additional motion of the perigee and the variable force, the extreme range of values of the magnetic moment is never nearer to unity than is the ratio 5/7. That is, the maximum variation from the mean is at least 15 per cent, and its period must be in the neighborhood of 270 years.

A magnetic attraction between the earth and moon has, however, a relatively greater effect on the precession and nutation of the earth than on the motion of the center of the moon, since the principal part is a couple, and the force we have been considering is small compared with this couple. An idea of the maximum magnitude of the assumed forces can be thus obtained. The ellipticity of the earth's surface, as measured by Clarke, is 1/293. The formulæ of precession and nutation, combined with an assumed equipotential surface for the earth, give an ellipticity to the latter of 1/297. The observed coefficient of the nodal term in the motion of the moon gives an ellipticity of a similar order of magnitude. The difference between the two values quoted amounts to about 1/70 of the whole. This limits the resolved part of the magnetic moment along the lunar axis of rotation to 1/70 of the earth's ellipticity. Hence u_0/r^3 must be less than one-half of u_1/r^3.

The formulæ of precession compared with observation do not exclude such a variable part. The amount of the precession in 70 years is 3600″, and the maximum change in this time due to a variable force of the magnitude considered is about 2″. The degree of accuracy attained by observation does not exclude such a coefficient. It might even be possible to detect it, but the investigation would have to extend over the whole range of known observations, and a very large number would be required.

The effect on the constant of nutation is relatively larger,—about 0″·1 to 0″·2 in a constant of 9″·2. This, again, is not excluded by the observations. To detect it with any certainty we should need from five to ten periods of 18 years each.

We must conclude, then, that a variable force with a period of 270 years and a maximum value about 1/120 of that produced by the earth's ellipticity is not excluded by the observations. If such a force exists with a potential $(u_0+u_1)/r^3$, so that it may be treated as an addition to the earth's ellipticity, we must conclude that the constant part of the addition is less than 1/70 and the variable part less than 1/120 of that caused by the earth's ellipticity.

Either of the two forms of the hypothesis which are admissible, an oscillation of a lunar magnetic axis about a mean position in the lunar equator, or a variable moment with an axis near the lunar axis of rotation, are difficult. There is, however, still another effect not yet considered, and one which, though secondary, is somewhat remarkable. It will be seen in the next section that a minute libration of the moon can, under certain circumstances, have a large effect on its motion. Now any supposed magnetic attraction between the earth and the moon will have its greatest effect in altering the direction of the axes of figure of the moon. The force is the same as that which would affect the precession and nutation of the earth, but its effect is 80 times as great, in general, owing to the earth's mass being 80 times that of the moon. The possibilities in this direction will be considered in § 10.

9. *The effect of the physical libration of the moon's axes.*—It can be shown that if we adopt the ellipticities of the moon's figure as being of the order of magnitude determined by observation, an oscillation within the plane of the lunar equator of the axes lying in that plane with a period of 270 years and a coefficient of 50″ will produce the observed inequality in the moon's motion.

The physical librations of the moon are of two kinds, free and forced. The forced librations, produced by the motion of the moon round the earth, are for that reason powerless to cause any sensible effect on its motion round the earth,—a result which can be deduced from the equations of motion. There are theoretically three principal free librations each with its own period, dependent on the three ellipticities of the principal sections of the moon's surface. The amplitudes of these librations have not yet been observed and it is generally assumed that they are zero or at least beyond detection by the observations hitherto made. The ellipticities, nevertheless, can be obtained from the forced librations and thence the periods of the free librations.

The libration along the lunar equator of that principal axis of the moon which is directed towards the earth would have, according to theory, a period of between two and three years: the value is doubtful. The period of the second libration is very nearly equal to a month. On examination it is seen that neither of these can cause any sensible effect unless it had an amplitude which would have been detected by observation.

The third libration has a period of between 200 and 300 years. The time is suggestive but its direction of motion is perpendicular to the moon's equator. In order to affect the motion of the moon's center sufficiently it would have to give rise to a libration within the moon's equator. The theory of the motion of the moon about its center of mass must be worked out to a higher degree of accuracy than yet obtained in order to find out whether there may be a long-period term of the kind and size required. On the observational side sufficient material has not yet been accumulated to test the existence of terms of very long period.

An angular change of 100″ in the position of any axis of the moon is the smallest amount which can be detected by a single observation, with the methods hitherto used. The recent work of Mr. F. T. M. Stratton* shows clearly how doubtful the constants of the moon's physical constitution are. This is to be expected, since the librational coefficients from which these constants are determined are of the orderof 100″. Hence a long-period vibration of 50″ is not at present excluded either by theory or observation.

10. A well known difficulty in the theory of the rotation of the moon is the fact that the ellipticities, as determined from observation, are some sixteen times as great as the ellipticities obtained on the assumption that the outer form of the moon is a level surface. It has already been mentioned that a magnetic attraction between the earth and the moon would produce the largest relative effect on the rotation of the moon. It may be suggested that the forced vibrations which are observed have their origin mainly in a magnetic attraction rather than in the gravitational attraction hitherto considered. The general effect is quite similar.

Nevertheless the free librations in any case depend on the ellipticities alone. If we calculate the free libration in the equatorial plane with the theoretical ellipticities first mentioned, the period, instead of two or three years, becomes 14 years, and this may be still further increased by non-rigidity.

A free period of 17 to 20 years is effective in producing inequalities with long periods and large coefficients in the motion of the moon's center of mass. This is due to the near coincidence with the period of revolution of the moon's node. But since the amplitude of the inequality in the moon's motion is directly proportional to the ellipticity, the amplitude of the free libration must be proportionally increased so that it would have to be of the order of 800″. It seems doubtful that such a large term should have escaped detection.

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* Memoirs Roy. Astron. Soc., vol. lix, pt. iv.

The results of these various computations are therefore not, on the whole, favorable to the hypothesis that a librational term causes the long-period inequality in the moon's motion. But the magnitudes of the forces which have been considered are so small that a more careful examination into the question of the whole effect of a magnetic attraction on the motion of the moon about its center of mass seems to be a desideratum, in view of the discordance between the theoretical and the observed ellipticities. This is not the object in view here, but the effects are not confined to any one class of observations and it may be possible to obtain evidence from various sources by which the question can be settled.

Yale University, April 7, 1910.

ART. XLVI.—*The Use of Silver in the Determination of Molybdenum, Vanadium, Selenium and Tellurium;* by CLAUDE C. PERKINS.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxi.]

IN former papers from this laboratory a process for the gravimetric determination of free iodine by means of specially prepared electrolytic silver* and the application of the same process to the determination of combined iodine and other halogens and the estimation of those oxidizers† whose reaction with potassium iodide is definitely known to set free iodine quantitatively have been described. The object of the work described in the present paper was the application of the same process to the determination of some of the rarer elements and the study of the reaction of their oxides upon hydriodic acid in the presence of silver.

To test the reaction of a soluble molybdate upon combined iodine in the presence of silver, a standard solution was made from a weighed amount of ammonium molybdate in which the percentage of molybdenum trioxide had been determined by fusing with a weighed amount of sodium tungstate which contained just enough tungstic acid to insure the absence of carbon dioxide. The ammonia was thus driven off and the amount of molybdenum trioxide was found from the increase in weight of the sodium tungstate.‡ Definite amounts of this solution were added to an excess of potassium iodide, made acid with hydrochloric acid and shaken with the electrolytically prepared silver under an atmosphere of hydrogen. From the increase in weight of the silver the amount of molybdenum trioxide was calculated on the assumption that one molecule of molybdenum trioxide liberates one atom of iodine with the results shown in Table I. These results would tend to show that the reaction takes place according to the following equation:

$$2MoO_3 + 4KI + 4HCl = 2MoO_2I + 4KCl + 2H_2O + I_2.$$

TABLE I.

Ag taken grm.	MoO_3 taken grm.	I_2 found grm.	Calculated MoO_3 grm.	Error grm.
2·0002	0·2127	0·1869	0·2120	—0·0007
2·0006	0·2127	0·1874	0·2126	—0·0001
2·0012	0·2127	0·1870	0·2121	—0·0006
2·0048	0·2127	0·1876	0·2128	+0·0001
2·0000	0·2540	0·2242	0·2543	+0·0003
2·0004	0·2909	0·2571	0·2916	+0·0007

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* This Journal, vol. xxviii, 33, 1909. † This Journal, vol. xxix, 338, 1910.
‡ Gooch and Norton, this Journal, vol. vi, 168, 1896.

In testing the reaction of a soluble vanadate with potassium iodide an exactly analogous process to that used in the case of molybdenum was carried out. The ammonium vanadate was fused with sodium tungstate to determine the amount of vanadium pentoxide contained in it. A known amount of the vanadate was shaken with potassium iodide, hydrochloric acid, and the silver, and the results calculated on the assumption that one molecule of vanadium pentoxide liberates two atoms of iodine. The results shown in Table II would indicate that the reaction takes place according to the equation:

$$V_2O_5 + 2HCl + 2KI = V_2O_4 + H_2O + 2KCl + I_2.$$

TABLE II.

Ag taken grm.	V_2O_5 taken grm.	I found grm.	Calculated V_2O_5 grm.	Error grm.
2·0012	0·1946	0·2699	0·1939	−0·0007
2·0012	0·2051	0·2856	0·2051	±0·0000
2·0024	0·1964	0·2746	0·1972	+0·0008
2·0024	0·2362	0·3295	0·2367	+0·0005
2·0062	0·2953	0·4106	0·2949	−0·0004
2·0062	0·2681	0·3729	0·2679	−0·0002
2·0527	0·5770	0·8038	0·5774	+0·0004
2·0006	0·2035	0·2829	0·2032	−0·0003

With selenium and tellurium it was found that the reduction proceeded to the end, giving the free elements, so that in weighing the residue of silver and silver iodide the amount of selenium or tellurium taken was included. The results obtained indicate that the reactions between selenium dioxide and potassium iodide and between tellurium dioxide and potassium iodide proceed according to the following equations:

$$SeO_2 + 4KI + 4HCl = 4KCl + 2H_2O + Se + 2I_2.$$
$$TeO_2 + 4KI + 4HCl = 4KCl + 2H_2O + Te + 2I_2.$$

The selenium used was carefully purified by twice crystalizing from nitric acid solution as selenium dioxide and resubliming in the presence of manganese dioxide. Definite amounts of a standard solution of selenium dioxide were added to an excess of potassium iodide in acid solution, and shaken with a weighed amount of the silver under the atmosphere of hydrogen. The increase in weight should represent the iodine liberated plus the selenium taken. The results in Table III were calculated upon the assumption that one molecule of selenium dioxide liberates four atoms of iodine, which gives 13·49 per cent of the increase in weight as the amount of selenium taken.

TABLE III.

Ag taken grm.	Se taken grm.	Increase grm.	Calculated Se grm.	Error grm.
2·0133	0·0050	0·0365	0·0049	—0·0001
2·0133	0·0075	0·0529	0·0071	—0·0004
2·5639	0·0126	0·0894	0·0121	—0·0005
2·5639	0·0428	0·3178	0·0429	+0·0001
3·0018	0·0504	0·3799	0·0501	—0·0003

In determining tellurium the dioxide was prepared from the basic nitrate by heating to drive off the nitric acid and the residual tellurium dioxide was heated to constant weight. Definite amounts of a standard solution, made from this product of tellurium dioxide, were added to an excess of a solution of potassium iodide, made acid with hydrochloric acid, and the whole shaken with a weighed amount of the silver under an atmosphere of hydrogen. The increase in weight represents the iodine set free plus the amount of tellurium taken. The results in Table IV were calculated upon the assumption that one molecule of tellurium dioxide liberates four atoms of iodide which gives 20·07 per cent of the increase as tellurium.

TABLE IV.

Te = 127·5

Ag taken grm.	Te taken grm.	Increase grm.	Calculated Te grm.	Error grm.
2·0152	0·0330	0·1654	0·0332	+0·0002
2·0152	0·0990	0·4931	0·0989	—0·0001
2·0815	0·0528	0·2635	0·0529	+0·0001
2·0815	0·0660	0·3294	0·0661	+0·0001
2·0815	0·0990	0·4948	0·0993	+0·0003
2·1693	0·1650	0·8240	0·1654	+0·0004
3·0126	0·1650	0·8258	0·1657	+0·0007
3·0126	0·0660	0·3302	0·0663	+0·0003

The results show that molybdenum, vanadium, selenium, and tellurium, may be determined gravimetrically by making use of the reaction of their oxides in liberating iodine from potassium iodide in an acid solution and combining the free iodine with the specially prepared silver.

ART. XLVII.—*Chemical Composition of Hulsite and Paigeite;*[*] by WALDEMAR T. SCHALLER.

Introduction.

IN the April number of this Journal for 1908[†] in conjunction with Mr. Adolph Knopf, who discovered these minerals in Alaska, I published a description of two new borates, hulsite and paigeite. These borates contained both ferrous and ferric iron, magnesia, and a small amount of water. The boric acid was determined by distillation with methyl alcohol and subsequent weighing as lime borate. Only a single determination of the B_2O_3 was given for each mineral. As, however, both analyses footed up well and the ratios, moreover, were fairly close to simple numbers, no doubt was entertained as to the correctness of the results given.

Shortly after, Prof. Clarke informed us that the method of determining boric acid in minerals was being investigated by two students of Prof. Edgar F. Smith, of the University of Pennsylvania. On entering into communication with Prof. Smith, we were enabled to have the boric acid content of both new minerals redetermined by methods devised by E. T. Wherry and W. H. Chapin.[‡] It was found that the values first obtained were erroneous, being much too high.[§] On again examining the minerals, therefore, to account for the deficiency, tin was found to be present in appreciable quantity in both minerals. It therefore became necessary to revise and extend the original analyses in order to definitely fix the composition of these minerals.

Notes on Chemical Examination.—These borates, having very similar composition, contain ferrous and ferric iron, magnesia, tin, water, boric acid, and there are in addition present in the HCl solution of the sample, silica, alumina and lime, derived from the gangue.

After considerable work performed on these two minerals, the results herein presented were obtained, but the unsatisfactory character of the determinations is fully recognized. A complete revision of all the chemical data is highly desirable, but for this pure material, free from any interfering gangue, is necessary, and for the complete elucidation of the problem considerable material must be available.

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[*] A brief abstract of a much fuller paper which is to appear in a forthcoming Bulletin of the U. S. Geological Survey.

[†] Knopf, A. and Schaller, W. T., Two New Boron Minerals of Contact Metamorphic Origin, this Journal (4), vol. xxv, p. 323, 1908.

[‡] Determination of Boric Acid in Insoluble Silicates, Jour. American Chem. Soc., vol. xxx, p. 1687, 1908.

[§] This Journal (4), vol. xxv, p. 323, 1908.

The present investigation was carried out under two great disadvantages, namely, (1) paucity of material, and (2) the unavoidable presence of considerable gangue in the samples. For the hulsite samples, free from magnetite, less than a gram was available, while several grams of paigeite, as pure as possible, had to suffice. Various questions developed only after some of the analyses had been completed, so that additional material was often needed but could not be had. It was found, too, that the different samples of each mineral varied somewhat in composition due to the different quality and quantity of the gangue and also to isomorphous replacements in the minerals themselves. All these points, developed as the analyses progressed, served to render the results obtained unsatisfactory to the analyst.

Analyses of hulsite.

Three different samples of hulsite were obtained and analyzed, the first two being the ones given in the original paper. Sample No. 1 consisted of about half a gram of magnetite-free hulsite, which was partially analyzed, only ferrous and ferric iron, magnesia, and the insoluble matter being determined. Sample No. 2 was about a gram of material, consisting of a mixture of hulsite and magnetite with but a few per cent of insoluble gangue. Tin was not determined in either of these samples and the value for boric acid given below for sample No. 2 was furnished by Wherry and Chapin.* Sample No. 3 was obtained by reëxamining all the available material and picking out a small amount of non-magnetic hulsite mixed with considerable gangue. The relatively large amount of the gangue that was soluble in acid complicated the discussion of the results.

Only the average of the analyses of samples Nos. 1 and 2 are repeated below, the fuller data being given in the original paper.

Average analyses of samples Nos. 1 and 2, hulsite.

	No. 1.	No. 2.
FeO	33·27	34·44
MgO	10·17	8·48
Fe_2O_3	17·83	27·64
B_2O_3	----	10·44
H_2O	----	1·66
Insol.	10·00	2·24
SnO_2	not det.	not det.

From the analysis of sample No. 3, the ratio of B_2O_3 to Fe_2O_3 is found to be 3 : 2. From this ratio the amount of magnetite present in the above sample No. 2 can be calculated. The amount of ferric iron belonging to the borate being thus determined, the amount belonging to the magnetite is found, and deducting the proper amount of FeO to form $FeO.Fe_2O_3$, the ratios reduce to the figures given beyond, which represent the composition of the magnetite-free hulsite.

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* Loc. cit.

The results obtained for the analyses of sample No. 3 are given below. Though considerable insoluble gangue was present, magnetite was entirely absent. The results shown under 1a were made on a small sample of still impurer material aud is chiefly of value for the determination of the tin, as the value confirms the other figures given for tin. The ammonia precipitate for sample 1a was not determined, as it was used for various qualitative tests and the calcium precipitate was accidentally lost. The figures given under 1a are not taken into the average. The higher value for the boric acid under columns 1 and 2 is taken in the average instead of the mean of the two values, as the second determination given is believed to be low.

Analyses of sample No. 3, hulsite.

	1a	1	2	3	Average
FeO	----	----	----	27·71	27·71
MgO	3·62	----	4·13	4·45	4·29
CaO	----	7·98	9·82	9·54	9·11
Fe_2O_3	----	----	----	----	15·21
Total iron as Fe_2O_3	----	----	46·30	45·67	----
SnO_2	6·13	6·85	7·15	7·20	7·07
B_2O_3	----	9·20	8·27	----	9·20
Insoluble	27·42	19·92	17·52	18·44	18·63
H_2O, CO_2, SiO_2, Al_2O_3	----	----	diff.	----	8·78
					100·00

From the figures given above for the average analysis the ratios were calculated with the following values:

Ratios of analysis of sample No. 3, hulsite.

FeO	·385	10·47
MgO	·107	
Fe_2O_3	·095	2·02
SnO_2	·047	1·00
B_2O_3	·131	2·79

The analyses of samples No. 2 of paigeite, as given beyond, give an indication of the amount of calcium oxide which may be derived from the gangue. For 15 per cent insoluble matter the calcium oxide content is about 4 per cent. If this ratio remains fairly constant, there should be, in the above analysis of hulsite sample No. 3, about 5 per cent of lime obtained from the gangue. This would leave approximately somewhat less than 4 per cent CaO which may belong to the borate mineral. Assuming this to be so, the ratio of (FeO, MgO, CaO) to Fe_2O_3 would become 11·9:1 or nearly 12:1. From the analysis of sample No. 3, given above, we obtain for the formula of hulsite, then, either $10\frac{1}{2}RO.2Fe_2O_3.SnO_2.3B_2O_3+?H_2O$, or regarding the 4 per cent of CaO as belonging to the mineral, the formula $12RO.2Fe_2O_3.SnO_2.3B_2O_3+?H_2O$.

Discussion of Formulæ of Hulsite.

From the results of the analyses of the three samples of hulsite, as just given, there are derived the following partial formulæ for the mineral.

Partial Formulæ for Hulsite.

	RO	Fe_2O_3	SnO_2	B_2O_3	H_2O
From Sample No. 1	13·2	2 0	--	--	--
" 2	12·4	2·0	--	3·0	1·9
" 3 } ...	10·5	2·0	1·0	2 8	-- or
" 3 } ...	12·0	2·0	1·0	2·8	--

From this compilation, incomplete as it is, the most probable formula derivable from the results obtained is $12RO.2Fe_2O_3.1SnO_2.3B_2O_3.2H_2O$ or $(Fe,Mg)_{12}Fe_4SnB_6H_4O_{31}$. In considering the relations of the various elements, it becomes almost impossible to consider hulsite as a borate of iron (ferrous and ferric), tin and magnesia, as the bases are present in overwhelming amount. Therefore, the ferric iron may be considered as present as an acid, playing the same rôle as the borates. On this assumption the above formula may be written: $R''_9(BO_3)_6.[R''_3[Sn(OH)]''' H_3(FeO_3)_4]$. The tin in hulsite is in a condition which is so easily soluble in dilute acid that it seems more probable to regard it as present as some form of stannic acid. The presence, however, of stannic acid, in combination with boric and possibly some iron acid, leads to a complicated subject on which it is best to, at present, pass by.

Analyses of Paigeite.

For paigeite, three different samples were prepared and analyzed. The amount of gangue varied slightly, but no such large variations in the amount were encountered as with hulsite. Sample No. 1 was the sample on which the first analyses were made. Tin was not determined in it, and the value given for B_2O_3 is the one determined by Wherry and Chapin. The average of the analyses is:

FeO	44·48
MgO	1·44
Fe_2O_3	16·72
H_2O	2·03
B_2O_3	9·83
Insol.	15·65

The other two samples were prepared from the specimens at hand, sample No. 2, consisting of finely-ground material, for which reason the value for FeO may be somewhat low. Sample No. 3 consisted of coarser material, otherwise very similar in character to that of No. 2.

Analyses of the second sample yielded the following results:

Analysis of sample No. 2, paigeite.

FeO	40·82	----	----	40·82
MgO	2·02	2·01	2·10	2·04
CaO	4·28	4·31	3·81	4·13
Fe_2O_3	18·19	19·34	18·48	18·67
Total iron as Fe_2O_3	63·54	64·69	63·83	----
SnO_2	3·15	3·14	3·26	3·18
B_2O_3	9·10	----	----	9·10
Insoluble	16·18	15·74	16·38	16·10
SiO_2, Al_2O_3, H_2O		by difference		5·96
				100·00

Considering all the lime as resulting from the solution of the gangue, the ratios deduced from the above analyses are:

Ratios of analyses of sample No. 2, paigeite.

FeO	·567	29·4
MgO	·051	
Fe_2O_3	·117	5·6
SnO_2	·021	1·0
B_2O_3	·130	6·2
H_2O	----	----

From these ratios the formula, incomplete in regard to the water content, is $29{\cdot}4RO.5{\cdot}6Fe_2O_3.1SnO_2.6{\cdot}2.B_2O_3. + ?\ H_2O$.

Analyses of the third sample yielded the following results. The evidence having indicated that the gangue was considerably dissolved by the HCl, direct determinations of the silica and alumina were made.

Analysis of sample No. 3, paigeite.

	1	2	3	Average
FeO	34·68	34·86	35·52	35·02
MgO	2·25	1·89	2·22	2·12
CaO	8·97	8·56	8·84	8·79
Fe_2O_3	14·69	14·84	15·18	14·90
Total iron as Fe_2O_3	53·22	53·57	54·62	----
SnO_2	2·77	2·86	2·76*	2·80
B_2O_3	----	6·71	7·16	6·94
Insoluble	18·62	18·81	18·29	18·57
SiO_2	3·28	2·78	3·25	3·10
Al_2O_3	2·51	2·41	2·09	2·34
H_2O, etc.		by difference		5·42
				100·00

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* A fourth determination of SnO_2 gave 2·97 per cent.

In the ratios of the above analysis, the CaO, SiO_2 and Al_2O_3 are excluded as belonging with the insoluble matter to the gangue. As obtained from the average analysis, they are:—

Ratios of analysis of sample No. 3, paigeite.

FeO	·486	28·5
MgO	·056	
Fe_2O_3	·093	4·9
SnO_2	·019	1·0
B_2O_3	·099	5·2
H_2O	----	

Like one of the hulsite analyses, the calcium oxide is considerably higher in sample No. 3 than in sample No. 2 and it seems as if some of the lime belonged to the borate. It would need only 1·57 per cent. of CaO to raise the ratio of (FeO+MgO+CaO) to SnO_2 from 28·5 : 1, as given above, to 30 : 1. This small amount of lime may, therefore, be considered as belonging to the borate. The ratios then obtained are 28·5 or 30·0 $RO.4·9Fe_2O_3.1SnO_2.5·2B_2O_3+$? H_2O.

Discussion of Formulæ of Paigeite.

From the above three series of analyses, the following are the formulæ deduced for paigeite:

Formulæ for Paigeite.

	RO	Fe_2O_3	SnO_2	B_2O_3	H_2O	
From sample No. 1	31·1	5·0	---	6·7	5·4	
" 2	29·4	5·6	1·0	6·2	---	
" 3	28·5	4·9	1·0	5·2	---	or
	30·0	4·9	1·0	5·2	---	

The average of the above shows that the most probable formula for paigeite and the one proposed for the mineral is: $30FeO.5Fe_2O_3.1SnO_2.6B_2O_3.5H_2O$. While the above formula is complex and yields a rather high ratio of FeO to SnO_2, there does not seem to be any other interpretation to the analyses. While not impossible that paigeite is a mixture of two or more closely related minerals, nothing but the unusual composition indicates such a mixture. The constant small percentage of tin oxide shows that the mineral is essentially different in ratios from the corresponding hulsite. The occurrence in wavy lamellar masses of fine radiating fibers, the intense shiny black color, the marked tendency as seen in thin sections for the individual fibers and masses to fray out at the ends into a bunch of very thin fibers, all differentiate this mineral from hulsite, which never shows any indication of fibrosity.

An alternative interpretation of the composition of paigeite is that it is a mixture of hulsite and a fibrous borate. Subtracting from the formula of paigeite the necessary amounts to include all the tin with the hulsite, the following results are obtained:

Paigeite =	30 FeO.	5 Fe_2O_3.	1SnO_2.	6B_2O_3.	5 H_2O	
minus hulsite	12 "	2 "	1 "	3 "	2 "	
there is left	18 "	3 "	.. "	3 "	3 "	or

$6FeO.Fe_2O_3.B_2O_3.H_2O$.

Should future investigation prove this to be the case, then the material now called paigeite would consist of a mixture of 1 part hulsite and 3 parts of the borate $6FeO.Fe_2O_3.B_2O_3.H_2O$, to which the name of paigeite could then be referred. However, on the evidence at hand, it is most reasonable to regard paigeite as homogeneous and with the composition ascribed to it.

To repeat, the formulæ now proposed are, for hulsite, $12(Fe,Mg)O.2Fe_2O_3.1SnO_2.3B_2O_3.2H_2O$, and for paigeite, $30FeO.5Fe_2O_3.1SnO_2.6B_2O_3.5H_2O$.

Chemical Laboratory,
U. S. Geological Survey.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A Gas containing Helium from the German Potash Deposit.*—**Ernst Erdmann** gives an account of an inflammable gas which was set free by a blast in the carnallite deposit of a shaft at a depth of 450 meters below the surface. When first liberated, 4½ years ago, it burned with a flame a yard long, and the pressure has since diminished only very gradually, and many thousands of cubic meters of the gas have escaped and burned. As an average of eight analyses the following results were obtained:

Hydrogen	83·6	per cent by volume.
Methane	4·4	" " "
Residue	12·0	" " "

The methane was found to be free from other hydrocarbons of the series, and the absence of oxygen, carbon dioxide, ethylene, and acetylene was established. The residue was found to contain a considerable amount of helium and also a little neon. These gases amounted to 0·17 per cent by volume of the original gas, or nearly one per cent of the residue, so that it was estimated that at least 12 cubic meters of helium and neon had escaped from the crack in the carnallite during the 4½ years of the flow of gas. It appears that Strutt had already detected a small quantity of helium in carnallite by dissolving the mineral in water.

In speculating in regard to the origin of the hydrogen the author is inclined to discard an ingenious theory advanced by Precht, that this gas arises from the reaction of ferrous chloride upon the water of crystallization of the mineral with the formation of hematite, a well-known constituent of the deposits. In fact, by heating appropriate mixtures in evacuated sealed tubes at 100–110° C. for 160 hours, no evidence of the formation of hydrogen or ferric oxide could be obtained. This experimental result, and the fact of the presence of helium, have led the author to advance the view that radio-activity has been the cause of the formation of hydrogen as well as of helium. Radio-active substances are supposed to have decomposed water into its elements, then the oxygen has reacted with ferrous chloride to form hematite, leaving the hydrogen. The radio-active bodies are supposed to have disappeared from the deposit, on account of being of shorter duration than uranium, which seems to be absent, and which has so long a life that it could not be expected to disappear in the time that has elapsed since the deposits were formed.

The author doubts that the feeble radio-activity of potassium is the source of the helium, although Strutt is inclined to take this view of the matter, for he argues that the helium is by no means uniformly distributed among the potassium salts, and, besides, there is no ground at present for assuming the production of helium from potassium.—*Berichte*, xliii, 777. H. L. W.

2. *Detection of Methyl Alcohol.*—A rapid and accurate method for the detection of this substance, particularly in the presence of ethyl alcohol, has been devised by G. Denigès. It is based upon the conversion of the alcohols into their corresponding aldehydes by the action of potassium permanganate under definite conditions, and the testing for formaldehyde by means of bisulphite-fuchsine under conditions that the author has worked out. He takes $0·1^{cc}$ of the alcohol to be tested in a test-tube, adds 5^{cc} of 1 per cent $KMnO_4$ solution, then $0·2^{cc}$ (not more) of pure H_2SO_4, and mixes. After 2 or 3 minutes 1^{cc} of 8 per cent oxalic acid is added, and the mixture is agitated. It rapidly becomes decolorized, and when a yellowish wine color is reached, 1^{cc} of pure H_2SO_4 is added and it is agitated again, when it becomes completely decolorized. Then 5^{cc} of bisulphited fuchsine solution are added, the liquid is mixed and allowed to stand, when a violet color, more or less intense according to the amount of methyl alcohol originally present, appears. The color usually reaches a maximum in about 15 minutes, it is very strong with 1 per cent of methyl alcohol, and is appreciable at a dilution of one-thou-

sandth. The Schiff's reagent may be prepared by adding to 1 liter of $\frac{1}{1000}$ fuchsine solution 20^{cc} of sodium bisulphite of 36–40° Baumé, and after 5 or 10 minutes adding 20^{cc} of hydrochloric acid of 1·18 density. In an hour or two the reagent is sufficiently decolorized for use.—*Comptes Rendus*, cl, 832. H. L. W.

3. *A Substitute for Platinum Wire for Use in Blowpipe Work.*—O. F. Kirby takes a few asbestos threads as straight and even as possible, dips them into phosphoric acid diluted with one or two parts of water, and heats them gently in the Bunsen flame until most of the water has been driven off. The threads, which are now attached to each other by the acid, but still flexible, are now carefully rolled between the fingers or on paper until a thin, even filament is produced, 2 or 3^{mm} in cross section. They are again carefully heated for a few minutes and finally finished in the blowpipe flame, when they are converted into a brittle rod or wire somewhat resembling porcelain. These rods give perfectly colorless borax beads which have little tendency to fall from the end. They are practically non-conductors of heat, and give no coloration to the non-luminous flame. They can be moistened with water or dilute acids without losing their rigidity, though when left in contact with these liquids for any length of time they become disintegrated and require re-heating before use. Though very brittle, pieces of about 8^{cm} in length will stand a good deal of usage, and pieces half as long may be used without risk of burning the fingers. They have been found to give excellent results in blowpipe work with large classes of students as a substitute for the more expensive platinum wire.—*Chem. News*, ci, 170. H. L. W.

4. *The Use of Sodium Hypobromite in the Separation of Certain Metals.*—Pozzi-Escott has found sodium hypobromite, in the presence of a large excess of caustic soda, a convenient reagent for separating iron and nickel from chromium, aluminum, and zinc. The operation consists in heating the acid solution to boiling, adding a large excess of the alkaline reagent, filtering upon nitrated cotton, dissolving in hydrochloric acid and repeating the precipitation. He recommends the method also for the determination of chromium, vanadium, and molybdenum in steels as more convenient than the method by use of an oxidizing fusion. These acid-forming elements pass into solution while nickel and manganese remain with the iron.—*Bulletin*, IV, vii, 160.

H. L. W.

5. *The Doppler Effect in Hydrogen.*—B. Strasser shows that the admixture of other gases with hydrogen influences the relative brightness of the stationary lines and the displaced ones. The purer the hydrogen the less bright is the stationary line—with a very pure gas only the displaced line is visible. Gases with larger atomic weights exercise a greater influence on the comparative intensity of the stationary and displaced lines than gases with lower atomic weights. The cathode dust also influences the relative intensities of these lines. A comparison is also made

between the displaced lines in the region near the cathode and at a distance. The value of $\frac{\varepsilon}{m}=10^4$ has obtained from the canal rays.—*Ann. der Physik*, No. 5, 1910, pp. 890–918. J. T.

6. *Effect of Dust and Smoke on the Ionization of Air.*—From the investigation of A. S. **Eve**, of McGill University, it appears that "the presence of dust, smoke, mist or other centres charged or neutral in the air causes a transformation from small to large ions. In this way, the total number of ions present may be increased, while the conductivity is diminished. In any region of air where a charge of one kind is predominant, the effect of the presence of centres, neutral or charged, is to increase and accentuate the excess. This tendency must have an important influence in the variation of the potential gradient and on the production of thunder storms."—*Phil. Mag.*, May, 1910, pp. 657–673. J. T.

7. *Measurements in the Extreme Infra-Red Spectrum.*—H. **Rubens** and H. **Hollnagel** show that the interferometer method is preferable to the diffraction grating method in the study of the infra-red region. They have employed a quartz-plate interferometer with "Reststrahlen" and have determined the wave lengths and energy distributions of the Reststrahlen of rock salt, sylvine, potassium bromide and potassium iodide and have obtained a relation between the molecular weight and the mean wave length. The index of refraction of water for $\lambda=82\cdot3\ \mu$ is of the same order as in the visible spectrum. By the investigation of Reststrahlen the optical spectrum has been extended 2/3 of an octave. Its complete extent is now 10 octaves—two of which are in the ultra-violet, one in the visible and seven in the ultra-red.—*Phil Mag.*, May, 1910, pp. 761–782. J. T.

II. GEOLOGY.

1. *Paleogeography of North America;* by **Charles Schuchert**. "Dedicated to those two great leaders in Geology and Stratigraphy, James Dwight Dana and Eduard Suess." Bull. Geol. Soc. Amer., vol. xx, pp. 427–606, pls. 46–101, 1910. Presented before the Society December 30, 1908.—With due regard for the other important contributions to paleogeography which have appeared during the course of the past generation and especially within the past few years, this may still be held the most important single contribution to the subject which has yet been published. Working for many years in the front rank of invertebrate paleontologists, the author's interests have broadened beyond the organisms to the inferences which their relationships imply as to the extent, connections, and durations of the continental seas. Although the concurrence of conclusions from several branches of geologic knowledge is required to attain reasonably safe

results in interpreting ancient distributions of lands and seas, the most important of these is clearly a masterly knowledge of paleontology. The thirty-eight years spent by the author in studying this subject have therefore formed the necessary personal preparation, while the growth of the several fields of geology through the labors of others has supplied a wealth of literature and made possible results which could not have been achieved in any previous decade.

The first 83 pages of the paper give a history of paleogeography from the first maps of J. D. Dana to the present time, and a statement of its methods. This is followed by a discussion of the influences which enter into the shifting of the strand line. A geologic history of the North American seas is also included. The final 77 pages give a description of the maps which follow and the new classification of geologic time suggested by them.

The first distinctive point to be noted in regard to this work consists in the large number of maps, fifty-seven having been prepared and fifty-three published, each representing a separate time interval, and the whole covering geologic time from the Lower Cambrian to the present. The diagram of fluctuating sea levels (pl. 101) indicates that at least this number of maps was necessary in order to reveal graphically the successive important movements that have occurred. All previous maps are therefore too synthetic in that each covers so long a time interval that significant changes of land and sea are concealed.

The second distinctive feature lies in the importance given to disconformities and the cartographic restriction of the original limits of the seas in the direction of the ancient land masses to a short distance beyond the farthermost determined outcrops of their sediments. As is noted by the author, this method may err on the side of too much restriction of the continental seas (p. 446). Most previous maps, both by representing a longer period of time and freely extending the seas beyond the limits of the sediments, have, on the other hand, tended to make the seas too extensive in time as well as in space. By consistently following his method the author is enabled to construct a diastrophic curve (plate 101) which shows the percentages of the present area of North America and of the United States which were exposed as land at each succeeding stage. This is one of the most important features of the paper. It brings out the diastrophic basis for grouping the geologic periods into eras delimited by revolutions, during which practically the whole continent stood for a longer or shorter time above the sea level. On the major rhythm are superimposed the secondary diastrophic waves, each of which marks a transgression and recession of the sea and comprises a geologic period. Defined on this basis, the Cambrian and Ordovician are broken up into three periods each and the Mississippian into two, called by Schuchert the Mississippic and Tennesseeic. The first of these is not, in North America at least, diastrophically distinct from the Devonic, the change being marked faunally rather than by shiftings of the seas. The fifty-seven maps were planned to bring out this diastrophic basis for the geologic periods, but beyond these earth movements of the second order, which separate the periods, are progressively smaller ones of the third and higher orders which the maps and the curves constructed from them cannot show. For these the maps are still too synthetic.

A study of the work gives a very different impression as to the character of North American paleogeography from that conveyed by the older maps which figure in many text-books. The latter show North America almost submerged at the beginning of the Paleozoic and gradually emerging during the progress of that long eon. The recent maps of Chamberlin and Salisbury, and also those of Willis and others, show quite a wide departure from this older conception, but Schuchert's bring out one totally different. In the latter the amount of North America covered by sea during eleven transgressions and ten emergences up to the end of the Carboniferous averages 22 per cent, but the transgressions being regarded as the longer phases, their average of 29 per cent represents the more permanent amount of water area. Furthermore the maps do not show a gradual emergence and growth of the continent such as have been formerly postulated, but on the contrary far-reaching oscillations of the sea. This is the dominating fact, but it is still true that after the greatest transgression of the middle Ordovician each later inundation covers somewhat less area. There is thus expressed graphically and powerfully what has in recent years come to be believed by many geologists, that wide oscillations of continental seas, producing alternate intermingling and isolation of their faunas, rather than a gradual retreat of the seas, was the controlling principle of Paleozoic time. The maps in connection with the discussions of the text give also a conception of the topographic relief of the continent during this greater part of the fossil-bearing earth record. The thin and patchy sediments representing many epochs and the wide prevalence of limestone, the numerous disconformities, only recognizable by finding hiatuses in the fossil record, indicate the reign of extremely shallow seas lying on lands which barely rose above their level. Except for the systems of axes on the two sides of the continent which were elevated from time to time and shed great quantities of waste into the neighboring troughs, the continent was awash. Across now one and now another part of this continental interior the ocean rolled on and off in waves whose periods were measured by more than a million of years.

A review of so important a paper as this should not, however, contain a mere summation of contents but also to some extent an examination of the principles upon which it is constructed. Professor Schuchert argues that unlike but synchronous faunas of otherwise similar environment could not in the Paleozoic be explained by differences in temperature of ocean waters or by sea currents, but the existence of land barriers must be postulated to separate them. Furthermore he holds that wide and shallow seas could not be broadly subject to bottom scour in the way now observed in limited localities, but would record their presence by means of sediments. These two principles as rules of very general though of course not universal or rigid application seem well taken and give definiteness to the problem. In regard, however, to the valuation of the disconformities some departure of view may be held from that which the author entertains. He states:

> "Neither can it be admitted that . . . extensive sheets of limestone have suffered erosion. If the latter were true, outliers of these missing horizons would be found, for the land was so low that the wearing away could not have removed them completely over hundreds of miles of extent" (p. 442).

That is, the disconformity is valued as entirely a land interval rather than as partly a sea interval, A, followed by a land interval, B, during which the sediments of time, A, are removed. The reviewer would consider that A instead of being of negligible value may comprise almost any part of the entire value A + B of the disconformity. Blackwelder has well discussed this idea in the "Valuation of Unconformities"* and Gilbert has clearly called attention to the fact that we are ignorant of the maximum extent of the great transgressions and still more ignorant of the former maximum areas of lands, since the landward sediments are immediately subjected to erosion upon the least retreat of the sea and continue to be eroded through all later time. The seaward limits of the greater unconformities are, on the other hand, forever concealed.† This paper of Gilbert's, so far as the reviewer is aware, is the first in American literature to call in question the general conception prevailing until recent years of the continuous reign of the Paleozoic continental seas. The questions raised by Gilbert are strikingly answered in the affirmative through the investigations of the past decade. The exceptional preservation of outliers of the great transgressions hundreds of miles from the nearest regular outcrops, in some places by downfaulting, in others by fossiliferous fragments having fallen down fissures and so escaping erosion, indicates how accidental is our knowledge of the supposed limits of the great transgressions. Limestones furthermore being subject to attack by solution are the most reducible of formations in a humid climate, as indicated by the broad limestone valleys rapidly developed at baselevel. Consequently under a suitable climate it is to be expected that outlying sheets left above baselevel might be completely dissolved away without leaving a trace of their former existence. The theory of probabilities would indicate that the plane surface of disconformities should more often be due to unlimited though slight emergence of the land with following subaërial planation, aided to some extent by marine planation, rather than that uplift of the land should take place until it was exactly flush with the surface of the sea. Schuchert's diastrophic curves are therefore presumably too limited in width of oscillations and too smooth. The latter point is illustrated by the Pleistocene, which is shown on his curve as a straight line representing gradual emergence of the continent to its present state, whereas it is known from the drowned river valleys that geologically rapid and profound oscillations have occurred and the continent now stands notably lower than in that portion of the Pliocene when the mature valleys now submerged were excavated.

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* Blackwelder, Jour. Geol., vol. xvii, pp. 289–299, 1909.

† Continental Problems, Bull. Geol. Soc. Amer., vol. iv, pp. 178–189, 1892.

On the other hand, the study of faunas indicates that no great oscillations have been missed and by adopting the most conservative method of mapping Schuchert finds the marked oscillations which give him the basis for the new time scale. The result proves the wisdom of caution in extending the limits of the seas. But while the permanency of these maps and their great value as a basis for future work is fully recognized, extensions of the seas will probably be made in many cases by using symbols such as Chamberlin and Salisbury and Willis have employed to indicate probable but unprovable extensions beyond the limits set by Schuchert.

Passing next to that part of the paper which deals with the causes rather than the results of paleogeographic change, the great debt owing to Suess is made apparent. The chief cause of the world-wide inundations is ascribed to the erosion of the lands and the filling in of the seas, so that an erosion cycle is also an inundation cycle. The emergences are ascribed to crustal movements which increase the relief of the earth, chiefly by increasing the volume of the ocean basins. The broad movements of the strand line are therefore largely due, both negative and positive movements, to changes of sea level, more than to movements of the land, but it is especially in positive movements of the strandline that this is so. The problem, however, is by no means a simple one and the author classifies continental seas according to the dominant feature of their existence. The classification terms are not mutually exclusive, since he regards nearly all as *aggrading seas.* During the period of advance they will be *transgressing seas* and some of them will be *synclinal seas.*

To this valuable part of the paper exception may be taken, however, on two points. First, the author frequently ascribes vertical warps, even in the continental interiors, to "thrusts from the oceans," by which is meant of course "the oceanic crustal segments." But it will be seen that for the collapse of geosynclines situated *within* continental platforms and often far removed from the ocean basins, the *immediate* cause is a thrust between two continental elements while the *ultimate* cause is held to be the contraction of the earth's interior. Furthermore, horizontal thrust in the crust has at most only a remote connection with many vertical movements. "Thrusts from the oceanic segments" is therefore an expression to be cautiously used, but as the causes of earth movements constitute a subject not immediately connected with paleogeography the doubtful use of this term does not affect the conclusions of the paper.

The other point on which difference of opinion may be held is regarding a looseness in the use of the terms *syncline* and *anticline*, a looseness which may be noted not infrequently in paleontologic literature.

In this paper syncline is used indiscriminately for syncline geosyncline and downwarp, and anticline for the contrary terms. At the present time it is well recognized that synclinal and anticlinal folds are adjustments to horizontal pressure dependent upon stratified structures and die out in the deeper and unstratified crust. Their size is determined by the competency of the stronger beds to resist stress. For those broader axial folds which involve the deeper crust and are generated by isostatic as well as compressive forces, Dana has provided the terms *geosyncline* and *geanticline*. For the combination of smaller folds superimposed on greater, Van Hise has used the terms *synclinorium* and *anticlinorium*, though as Rice has pointed out, his use of the term *synclinorium* is an unjustifiable departure from Dana's original definition.* For broad vertical regional movements not clearly defined but in which horizontal thrust appears to play no direct part, the physiographers have coined the terms downwarp and upwarp, or arch. While the examples grade toward each other, the types are markedly distinct and in paleogeography there would seem to be a gain by their clear recognition. To illustrate the use of these terms in their defined senses it may be said that it is the subsidence of geosynclines and the irregular downwarps of the negative continental elements which have determined the limits of the epi-continental seas. Downwarp may also be a preferable term to *basin* for such gentle depressions without raised rims as constituted the *Indiana* and *Ohio basins* of upper Paleozoic time. Usage, however, sanctions in this connection the word basin, though the same word is employed for intermontane depressions and the oceanic abysses.

J. B.

2. *Virginia Geological Survey*, THOMAS LEONARD WATSON, Ph.D., Director. Bulletin No. I–A. Annual Report on the Mineral Production of Virginia, 1908; by T. L. WATSON. Pp. 139, 25 figures and map. University of Virginia, Charlottesville, 1909.—The Report on the Mineral Production of Virginia contains not only statistical material well illustrated by maps, but also historical and general geologic information regarding the occurrences of rocks and minerals of value. A further interesting feature is the brief account of the general geology of the state. The mineral products discussed are as follows: Iron ores and pig iron, manganese ores, gold and silver, copper, lead and zinc, coal, coke, clay and clay products, lime and cement, sand

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* On the Use of the Words Synclinorium and Anticlinorium, Science, vol. xxiii, 1906, pp. 286, 287.

and gravel, sand-lime brick, stone, abrasive materials, silica, mica, feldspar, asbestos, talc and soapstone, barytes, gypsum, salt, mineral paints, marl, pyrite and pyrrhotite, arsenic, phosphate, graphite, rutile (titanium), monazite, mineral waters, precious stones. H. E. G.

3. *Geological and Archæological Notes on Orangia;* by J. P. JOHNSON. Pp. 102, 45 figures and bibliography. New York and London (Longmans, Green & Co.).—This volume might be called an expanded notebook on the geography of Orangia (Orange River Colony). It is the sort of description which is of interest to one who desires a knowledge of the country and its people. Interesting notes on climate, topography, on the diamond, coal and salt prospects are mingled with data regarding the plant and animal life of the region, population, history of settlement, and present social and industrial conditions.

The horizontally bedded rocks of the Karroo system extend over nearly the entire territory with the exception of rocks of earlier age exposed near Vredefort by planing down of an anticline by marine denudation. Chapters 3 and 4 are devoted to a discussion of the kimberlite dikes and pipes and the diamond mines. The superficial deposits give evidence of a change in climate during recent geologic time. Ancient spring deposits and buried sand dunes are in evidence. An interesting series of "pans" apparently corresponding to the "buffalo wallows" of North America are found in several localities. The larger pans are bounded on one side by large dikes which intercept the movement of ground water and determine the location of wells.

The prehistoric inhabitants of this district are discussed in chapters 6 to 8. Two distinct groups of stone implements, the Acheulic and the Solutric, have been found, the former supposed to be much older than the latter. The richness of the collections may be indicated by the fact that on one Solutric site there were gathered 1300 flakes and unfinished implements, as well as 700 finished flake tools. The petroglyphs and rock paintings of animals, men and mythological beings, which are figured in chapter 8, are especially interesting as indicating the stage of development of those prehistoric people. H. E. G.

4. *Handbuch der Regionalen Geologie;* herausgegaben von G. STEINMANN und O. WILCKENS. Heidelberg, 1910 (C. Winter).—The aim of the projectors of this work is expressed in the title. It is to produce a series of volumes which shall give in condensed form, and yet with sufficient detail, an account of the regional geology of the entire world, so far as now known. It is proposed to carry out the work in 8 volumes of about 600 pages each. The price per sheet, or signature, to subscribers is to be 50 pfennigs, or about 5 dollars a volume. In executing the work the authors will have the help of a great number of geologists, all the principal civilized countries being represented. One thought that the proposal immediately suggests is that the different volumes for practical use will have very different values.

Thus, for example, Germany, Bohemia, Denmark, Netherlands, and Belgium, with an area of say 260,000 square miles, are to be treated in one volume and one is also projected for the two Americas and Antarctica, or say 17,000,000 square miles. It is of course true that the geology of central Europe has been studied in relatively great detail as compared with the larger part of the Americas and that over wide areas the geology of the latter is on a simpler and broader scale, yet to compress only a part of what is known of this vast area into one volume will require so sketchy a treatment that, as a source of information for regional geology, its value can only be small, compared with the first volume mentioned. It is to be hoped that as the work proceeds this part may be enlarged and more contributors added, if it is to have an international scope and use.

The first sample of the work to appear now lies before us. It is vol. 1, part 2, and covers Denmark. It is from the pen of Prof. N. V. USSING of Copenhagen. It is a masterly presentation of the subject and, in the 38 pages allotted, a remarkable amount of detailed information is conveyed, relating to physiography, stratigraphy, fossils, geological history, tectonics, resources of economic value, etc. and a full bibliography. It is an excellent model for the entire work. L. V. P.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *United States Coast and Geodetic Survey. Report of the Superintendent,* O. H. TITTMANN, *showing the Progress of the Work from July 1, 1908, to June 30, 1909.* Pp. 184, with 4 appendices and 10 pocket maps. Washington, 1909.—This report contains the usual statement of the work accomplished by the Survey during the year ending June 30th, 1909. It is accompanied by four Appendixes giving Details of Field and Office Operations (Nos. 1 and 2), also Results of Magnetic Observations for the time named (No. 3), and further (No. 4), the Distribution of Magnetic Declination in Alaska and adjacent regions for 1910. This last Appendix, as also No. 3, is by R. L. Faris and is accompanied by a chart giving the lines of equal magnetic declination and of equal annual change in Alaska for 1910.

The Survey has also issued another volume of the results of the observations at the permanent magnetic observatories; this is for the observatory at Sitka and covers the years 1905 and 1906. This report has been prepared by Daniel L. Hazard, and is accompanied by thirty-six figures reproducing the magnetograms for the principal magnetic storms.

2. *Connecticut Geological and Natural History Survey. Bulletin No. 14. Catalogue of the Flowering Plants and Ferns of Connecticut;* by a Committee of the Connecticut Botanical Society, consisting of C. B. GRAVES, E. H. EAMES, C. H. BISSELL, L. ANDREWS, E. B. HARGER, and C. A. WEATHERBY. Pp. 569.

Hartford, 1910.—This important work has been carried through by the above-named committee of the Connecticut Botanical Society without personal compensation, the State contributing $300 for incidental expenses. It gives a complete list, according to present knowledge, of the flowering plants and ferns growing without cultivation within the limits of the state; the names are, in general, those of the seventh edition of Gray's Manual. This list includes 1948 flowering plants and ferns; of these 1487 are believed to be native to the state and 461 to have been introduced by man either designedly or by accident. In addition there are numerous forms distinct enough to receive names although not given specific rank, bringing the total number of plants named in the book to 2228. The introduction gives an interesting history of botanical investigation in the state, beginning with that of Dr. Levi Ives (1819), and continued by many active workers; an appendix includes a statistical summary of the plants of Connecticut. Teachers of botany and all interested in our native plants will welcome this thorough and carefully prepared volume. Copies may be obtained from the State Librarian for seventy-five cents, or gratuitously, where needed by scientific men or teachers for professional use.

3. *Kraft das ist animalische, mechanische, soziale Energien und deren Bedeutung für die Machtenfaltung der Staaten;* von **Prof. Dr. E. Reyer.** Zweite Auflage. Pp. vii, 471, Leipzig (Wilhelm Engelmann), 1909.

Soziale Mächte als Ergänzung der Arbeit über "Kraft"; von **E. Reyer.** Pp. 111, 34 figures.—Readers of the earlier edition (see v. xxvii, 272) of Dr. Reyer's thoughtful discussion of this broad and important subject will be glad of this new edition, which takes into account the many recent factors in modern industrial progress.

4. *Publications of the Alleghany Observatory of the University of Pittsburgh.*—The following memoir of vol. I has recently been distributed.

No. 21. A Comparative Study of Spectroscopic Binaries; by **Frank Schlesinger** and **Robert H. Baker.** Pp. 135–161.

5. *Bulletin of the University of Kansas.*—The following has been recently issued: Engineering Bulletin No. 1 (vol. xi, No. 1), A Ballistic Electro-Dynamometer Method of Measuring Hysteresis Loss in Iron; by **Martin E. Rice** and **Burton McCollum.** Pp. 23, with 5 figs. Lawrence.

The Philosophy of Happiness: A Consideration of Normalism; by **R. Waite Joslyn.** Pp. 200. Elgin, Ill. (Normalist Publishing Co.)

La Vita Della Ricchezza; by **Emanuele Sella.** Pp. 252. Turin, 1910. (Fratelli Bocca, Editori.)

ALEXANDER AGASSIZ.

The sudden death of Mr. Agassiz was announced in the last number of this Journal. He was returning on the steamer "Adriatic" from a trip to Egypt and southern Europe, in company with his son Maximilian, and was apparently in about as good health as usual, of late years. He was found dead in his berth, on March 27th.

In his death the world has lost one of its most eminent scientific men, and probably the most liberal patron of natural science that this country has known.

He not only conducted, at great cost, numerous extensive explorations of the deep sea and coral islands and reefs in all the great oceans, but he personally wrote many of the volumes of reports on the results of his expeditions. Moreover, he induced many of his colleagues, both in this country and Europe, to write reports on his various collections, paying personally all the expenses of their publication, including the most liberal illustrations, and provided in his will for their completion, by a bequest of $100,000, besides an equal amount for the general uses of the Museum. His zoological and embryological works, both before and after his deep-sea explorations, were voluminous and of great importance, and his contributions to our knowledge of the physical geography and geology of all the great coral-reef regions are of inestimable value.

But aside from these investigations, the building up of the Museum of Comparative Zoology, from the comparatively small institution, with small funds, as it was left at the death of his father, into a magnificent museum, liberally endowed, and filled with a wonderfully rich collection, has been one of the great achievements of his life. He was not only its curator and director for many years, but also by far the most liberal of its patrons, for his gifts to the Museum amount to upwards of a million dollars.

However, to the world at large he is, no doubt, more widely known as the eminent mining engineer and financier, who developed and managed during many years the great Calumet and Hecla Copper mine, which made him and some of his friends wealthy. It is stated, in the Mining and Scientific Press, and in the Engineering News, that this is the greatest single copper mine in the world, and that it has paid in dividends over $110,000,000. Its wonderful success was due to his skill and energy. When Mr. Agassiz commenced to develop it in 1865–6, it was considered as almost worthless.

He was also interested in various other important lines of business. But his fame, apart from his scientific work, will, in the long run, depend rather upon the wise uses to which he devoted a considerable part of his fortune, than upon its acquisition.

Mr. Agassiz came to America in 1849, at the age of 14 years. He graduated at Harvard in 1855; in 1857 he took the post-graduate degree of B.S. in Civil Engineering; and in Zoology in 1862; LL.D., 1885. In 1859–60 he was employed in the Coast Survey, on the Pacific Coast, and on the Northwest Boundary Survey. While there he made some collections of the marine fauna for his father, and also sent him some very beautiful drawings of acalephs, actiniæ, etc., which the writer saw at that time, and with which his father, Prof. Louis Agassiz, was very much pleased. He returned to Cambridge, owing to the urgent desire of his father, to continue his zoological studies and especially to assist his father in the installation of the collections in the new Museum building, which had then just been built and was not finished. During the next few years he was an assistant in the Museum, associated with Lyman, Hyatt, Shaler, Putnam, Packard, Scudder, Morse, the writer, and others, many of whom have also passed away.

In 1866–7 he was induced to undertake the development of the Calumet and Hecla mine, on Lake Superior, where he remained as superintendent most of the time till 1869, and with which he was connected as president or director till his death. While there, in the early years, he experienced great hardships and exposure, and contracted an illness from which he never fully recovered.

He was appointed Curator and Director of the Museum, after the death of his father, in 1874 and retained that position till 1898, when he resigned it. He was also fellow of Harvard University, 1878 to 1884, and 1886–1890; overseer 1873–78 and in 1885, and became Director of the University Museum of Harvard in 1902.

He had been a member of the National Academy of Sciences since 1866, and for a number of years was its president. More recently he has been its Foreign Secretary, up to his death.

He was a member of a large number of other scientific societies, both in this country and Europe, and received numerous other honors.

Among his earlier scientific expeditions was one to the Andes and Lake Titicaca, in 1875, where he obtained many archeological and zoological specimens. From 1877 to 1880 he spent most of his winters in deep-sea dredging on the "Blake Expeditions," mostly in the West Indies and Gulf of Mexico. The collections thus obtained were very large and valuable and have given origin to many valuable reports. Mr. Agassiz himself wrote the general account of the work and its results in two volumes, "Three Cruises of the Blake." He also made trips to the West Indies and Bermuda, to study the geology of the coral reefs. He also made an extended exploration of the great Barrier Reef of Australia, in a steamer chartered for the purpose in Australia, in 1896.

About that time the writer remembers a remark that he made, in conversation, to the effect that he proposed to devote the rest of his life to the exploration and study of the coral-reefs and islands of the Pacific and Indian Oceans. In pursuance of this idea he obtained from the U. S. Government the use of the steamer "Albatross," of the U. S. Fish Commission, for several long trips, both for deep-sea dredging and coral-reef work. However, he personally paid the "running expenses," such as for the coal, oil, etc., and his scientific outfit and assistants. He told me personally that these trips and those of the "Blake" were often no pleasure trips for him, for they involved a great amount of hard work and much sea-sickness at times.

In 1891 he made his first cruise in the Albatross for deep-sea explorations of the Pacific Ocean off S. America, Central America, the Galapagos Islands, and Mexico; in 1897 he explored the coral reefs of the Fiji Islands; in 1899 and 1900 he made a very extended exploration of the Pacific coral islands, including the Marquesas, Paumotu, Society, Fiji, Ellice, Gilbert, Marshall, Caroline, Ladrone and other groups, and to Japan. In 1904 and 1905 he again explored the ocean depths off the west coasts of North and South America, extending his cruise to Easter Island and the Paumotus.

In December, 1901, and January, 1902, he explored the great Maldive Archipelago of coral islands in the chartered steamer "Amra," steaming 1600 miles among the islands. The fully illustrated report of this expedition by Mr. Agassiz is of great interest and value.

One of the most important results of his explorations of the coral islands was the complete confirmation of the view, already held by many geologists, that most coral reefs and islands, both Atlantic and Pacific, are built upon eroded banks and shoals of ancient rocks, and are not of such great thickness as had been supposed, nor ordinarily due to gradual but extensive sinking of the land, as Darwin and Dana believed.

Mr. Agassiz was less known and appreciated popularly than his illustrious father, but this was due partly to the fact that he wrote few popular works and delivered very few public lectures. Nor did he teach classes in the University. But his scientific publications exceed those of his father.

His specialties in Zoology were Hydrozoa and Echinoderms—especially the Echini, in which he was the leading authority. In Geology the structure and origin of coral islands and reefs were his specialties. Among his earlier papers, however, there is one on the embryology of annelids, one on the young stages of fishes, and another on the larval development of *Balanoglossus*.

The following list, which includes most of his more important publications, is by no means complete, but it will serve to give a good idea of the variety and great extent of his published works. He told the writer, a day or two before he started on his last trip, that he had other reports in preparation, and that he expected to do some work on them while away. He, also, at that time, authorized him to have 140 quarto plates printed for the report on the Alcyonaria of the Blake Expeditions. Most of his own publications, relating to his various explorations, if in quarto were published in the Memoirs of the Museum of Comparative Zoology, and the octavo ones in the Bulletin of the Museum.

Embryology of the Starfish. 4to, 8 plates. 1864.

North American Acalephæ. 248 pp., 4to, 360 text figures. 1865.

Preliminary Report on the Echini and Starfishes dredged in deep water between Cuba and the Florida Reef by L. F. de Pourtales. 54 pp. 8vo. 1869.

Revision of the Echini, 4to, 774 pp., with Atlas of 94 plates. 1872–1874.

Zoological Results of Hassler Expedition. I, The Echini. 4to, 23 pp., 4 plates. 1874.

Embryology of the Ctenophoræ. 41 pp. 4to, 5 plates. 1874.

North American Starfishes. Part I, Embryology of the Starfish. Part II, On the Solid Parts of Some North American Starfishes. 143 pp. 4to, 20 plates. 1877.

Palæontological and Embryological Development. 1880.

Report on the Echinoidea dredged by the Challenger. 321 pp. 4to, 64 plates. 1881.

Report on the Echini. Results of dredging by the Blake. 94 pp., 32 plates, 4to. 1883.

Three Cruises of the Steamer Blake, in the Gulf of Mexico, in the Caribbean Sea, and along the Atlantic Coast of the United States. 1877 to 1880. Two volumes, 8vo, 545 text cuts and maps. 1888.

Calamocrinus Diomedæ, a new Stalked Crinoid. 95 pp. 4to, 32 plates. 1892.

A Reconnaissance of the Bahamas and of the elevated reefs of Cuba in the steam yacht "Wild Duck," January to April, 1893. 203 pp., 4 plates. 1894.

A Visit to the Bermudas in March, 1894. 72 pp. 8vo, 30 plates and a map. 1895.

Acalephs from the Fiji Islands, 47 pp. 8vo, 17 plates. 1899 (with A. G. Mayer).

Preliminary Report, and List of Stations of the Albatross Expedition of 1899 and 1900, 114 pp. 4to, 21 charts. 1902.

The Coral Reefs of the Tropical Pacific. 443 pp. 4to, 238 plates. 1903.

The Medusæ of the Albatross Expedition of 1899–90. 40 pp. 4to, 14 plates. 1902 (with A. G. Mayer).

The Coral Reefs of the Maldives. 4to, 193 pp. and an atlas of 82 plates, 1903.

The Panamic Deep-Sea Echini, 254 pp. 4to, 112 plates. 1904.

Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, by the Albatross, 1904 to 1905. 75 pp. 4to, 96 plates and maps, 1906.

Many of the plates illustrate the huge prehistoric statues on Easter Island and the scenery of the Galapagos.

Hawaiian and other Pacific Echini. The Cidaridæ. 50 pp. 4to, 44 plates. 1907 (with H. L. Clark).

A visit to the Great Barrier Reef of Australia in the steamer "Croydon," during April and May, 1896. 55 pp., 42 plates, 1898.

The Islands and Coral Reefs of Fiji. 167 pp., 120 plates. 1899.

Hawaiian and Other Pacific Echini. 88 pp. 4to, 17 plates. 1908 (with H. L. Clark).

Echini: The Genus Colobocentrotus. 42 pp. 4to, 49 plates. 1908.

Hawaiian and Other Pacific Echini. The Echinothuridæ. 63 pp. 4to, 30 plates. 1909 (with H. L. Clark).

The Tortugas and Florida Reefs. 27 pp. 4to, 12 plates and maps, 1883.

The Porpitidæ and Velellitæ. 16 pp. 4to, 12 plates. 1883.

A. E. VERRILL.

Professor ROBERT PARR WHITFIELD was born at Willowvale, Oneida Co., N. Y., on May 27, 1828, and died at Troy, N. Y., on April 6, 1910.

Professor Whitfield's parents were English, and when young Whitfield was about seven years of age, in the fall of 1835, the family went to England. From England the Whitfields returned to America in 1841, finally locating at Whitestone, adjoining Utica, N. Y. Here Prof. Whitfield's scientific life began, and for a time, consonant with the promiscuous impulses which first start the naturalist in his course of observation, he turned his attention to many fields of natural history. In his twentieth year Prof. Whitfield married. For nine years he continued his vocation as a maker of philosophical instruments at Utica, but, through his membership in the Utica Society of Naturalists, was constantly associated with students of nature.

During these years he became acquainted with Colonel Jewett, and thus came in contact with a representative collection of fossils and shells, and the beginnings of his interest in paleontology, which finally excluded all other phases of scientific activity, were laid.

Through Colonel Jewett he became employed in the service of the New York State Survey under Prof. James Hall, and in Albany his scientific influences were strengthened, educational facilities increased, and a continuous intercourse with workers and leaders in science began. Meek, Hunt, Logan, Billings, Leslie, Safford, Agassiz, Conrad, Hayden, were a few names among the crowd of visitors to Prof. Hall's home, and in this multitudinous circle Whitfield's acquaintance with men of science was greatly extended.

His work was felt and illustrated in the publications of the Survey. He became lecturer in the chair of Applied Geology, at the Troy Polytechnic Institute, and in March 1876 resigned his position in Albany, and came to the American Museum of Natural History, where he installed the great Hall Collection of Fossils.

Besides his work on the New York Survey, Prof. Whitfield was engaged in work for the Ohio, Wisconsin, New Jersey and Black Hill Surveys, while papers furnished to journals of science, and the series of special studies published in the Bulletin of the American Museum of Natural History, complete his life of scientific activity.

Among contributions to science which merit the distinction of being classed as discoveries were his detection of the muscular impressions in "true Lingula" in the Trenton limestone, his observations on the internal appendages of Atrypa, his reference of the fossil forms *Dictyophyton* and *Uphantænia* to sponges, his description of a fossil scorpion from the Silurian rocks of America, his notice of new forms of marine Algæ in the Trenton limestone, the demonstration of *Balanus* in the Marcellus Shale, his papers on fossil teredo-like forms (*Xylophomya*), and the proof of three genera in a single individual of *Heteroceras*. The long series of papers on systematic paleontology, in which many new genera and species occur, with numerous observations in morphology and correlation, identify his name with American Paleontology. L. P. G.

Sir William Huggins, the veteran English astronomer, died in London on May 12, at the age of eighty-six years. He was one of the first to use the spectroscope in the study of the heavenly bodies, and the importance of his researches into the constitution of the comets, the stars and nebulæ can hardly be overestimated.

Professor **Knut Johan Ångström**, the eminent Swedish physicist, died on March 4, in the fifty-fourth year of his age. He was the son of Anders Johan Ångström, the pioneer worker in exact quantitative work on the solar spectrum, and his labors were devoted to the same field of solar physics ; his most important investigations had to do with absorption phenomena, particularly in the infra-red, and with the measurement of solar radiation.

Professor **Julien Fraipont** of the University of Liège, Belgium, died March 22, 1910, at the age of 53 years. At the time of his decease he was rector of the University and professor af animal geography and paleontology. Author of many papers on zoölogy, paleontology and anthropology and a member of many learned societies, including the Royal Academy of Belgium, Dr. Fraipont was perhaps best known for his work (issued in 1887 jointly with Professor Max Lohest) on the fossil race of Spy, entitled: La race humaine de Néanderthal ou de Canstadt en Belgique. Recherches ethnographiques sur des ossements humains découverts dans des dépôts quaternaires d'une grotte à Spy et détermination de leur âge géologique.

Dr. H. **Landolt**, Professor of Chemistry at the University of Berlin, died on March 14, at the age of seventy-eight years.

Dr. E. **Philippi**, Professor of Geology at Jena, and geologist to the German Antarctic Expedition of 1901–03, died in March.

Dr. **Richard Abegg**, Professor of Chemistry at Breslau, died on April 3, in his forty-second year.

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THE

AMERICAN JOURNAL OF SCIENCE.

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FOURTH SERIES

VOL. XXX—[WHOLE NUMBER, CLXXX.]

WITH TWO PLATES.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY
NEW HAVEN

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VOL. XXX. JULY, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

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FOURTH SERIES

VOL. XXX—[WHOLE NUMBER, CLXXX.]

No. 175—JULY, 1910.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

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Art. I.—*The Platinum-Rhodium Thermoelement from 0° to 1755°;* by Robert B. Sosman.

Contents:

1. Introduction and Plan.
2. Scale of Temperatures.
3. Melting Point of Platinum.
4. Interpolation.
5. Relation of Thermal E.M.F. to Composition.
6. Summary.

1. *Introduction and Plan.*

In two recent papers from this laboratory,[*] there have been published the results of a revision of the nitrogen thermometer scale from 400° to 1100° and of an extension of the scale to 1550°. The plan of that research was essentially as follows: it consisted, first, in selecting certain fixed thermometric points, usually melting points of metals, and in determining their reproducibility; second, in making a measurement of the true temperature on the nitrogen scale at or close by one of these fixed points; third, in transferring this known temperature by means of a thermoelement over to the fixed point in question. This transference by the thermoelement was necessary because the platinum-rhodium thermometer bulb could not be put directly into melting or solidifying substances at high temperatures.

A portion of the second paper[†] was taken up with a discussion of the standardization of the platinum-rhodium thermoelement. It was shown that the relation of thermal e.m.f. to temperature can be represented over the range studied (400° to 1550°) by two parabolic curves, by means of which temperatures between the standard melting points can be interpolated with an average accuracy of one degree.

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[*] Some New Measurements with the Gas Thermometer, A. L. Day and J. K. Clement, this Journal (4), xxvi, 405–463, 1908; The Nitrogen Thermometer from Zinc to Palladium, A. L. Day and R. B. Sosman, ibid. (4), xxix, 93–161, 1910.

[†] Loc. cit., pp. 121–128, 140, and 147–151.

Since this thermoelement can be conveniently used for the measurement of temperatures beyond 1550°, continuing up to the melting point of the platinum wire at 1755°, it was thought desirable to extend its interpolation curve to cover the region between palladium and platinum (1549°–1755°). In this region the thermoelement is the most accurate means we have for measuring temperatures. Below 300°, on the other hand, the sensitiveness of the platinum-rhodium element is very low compared with the platinum resistance thermometer, the copper-constantan thermoelement, or the mercury thermometer. Nevertheless, it is often convenient to use this element for measurements in the lower range; hence we have in addition determined the course of the thermoelement curve from 0° to 300°. The present paper contains the results of these extensions in the form of a table, which has been found very convenient in this laboratory for the thermoelectric measurement of all temperatures from 0° to 1775°.

In connection with the work on the nitrogen thermometer referred to above, some data were obtained on the thermal electromotive force of rhodium alloys of various compositions, which have been brought together with the few earlier determinations that are available, to show the relation of the thermal e.m.f. to the percentage of rhodium in the alloy.

2. *Scale of Temperatures.*

The melting and boiling points of pure substances form the best basis for the calibration of secondary measuring devices, such as the thermoelement, after these points have once been determined on the gas thermometer. The 0° and 100° points are familiar. In the neighborhood of 200° and 300° the boiling points of pure naphthalene and benzophenon were used. The best gas thermometer determinations of these two points, by Callendar and Griffiths,* and by Jaquerod and Wassmer,† differ by 0·26° at 218° and 0·4° at 305°. We have adopted the data of Jaquerod and Wassmer, until further gas thermometer measurements shall have brought out the reasons for these differences. The values are 217·68° for naphthalene and 305·44° for benzophenon, at 760^{mm} pressure.‡

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* Phil. Trans. Roy. Soc., clxxxii, A, 43-72, 119-157, 1892.

† Jour. Chim. Phys., ii, 52–78, 1904.

‡ The results of Jaquerod and Wassmer have been used as the standard since 1904 by the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology, in their work on electrical conductivity at high temperatures.

In our revision of the nitrogen scale from zinc to palladium,* one measurement was made at the melting point of cadmium, to give an indication of the course of the thermoelement curve. Being only a single measurement, this has not as much weight as the higher temperatures, which were measured under varied conditions. The value obtained was 320·0°. The difference between benzophenon and cadmium, determined with three thermoelements, is 14·9°, which agrees within 0·1° with a similar comparison made at the Bureau of Standards, using a resistance thermometer and different samples of the materials. On the basis of the benzophenon value adopted above, this difference makes the cadmium point 320·3°. We have arbitrarily connected the two portions of the temperature scale at this point by taking the mean, 320·2°, for cadmium. Since in this region temperatures cannot be conveniently obtained closer than 0·2° with the platinum-rhodium element, the values are abundantly accurate for our present purpose.

From zinc to palladium, we have used, throughout, the scale of temperatures published in our recent paper.†

It should not be overlooked that the value which we have used for zinc indicates a lower value for the boiling point of sulphur than the figure 444·5 now in general use. The four independent gas thermometer determinations that have been made of the sulphur point, although agreeing unusually well, are not free from the possibility of errors of several tenths of a degree, and this fact, taken together with the variability in the point itself with different experimental conditions, makes it probable that the absolute value given for the sulphur point is at least no more reliable than the value given below for the zinc point.

3. *Melting Point of Platinum.*

For the purpose of interpolating between the melting points of palladium and platinum, it was necessary to determine, on a number of thermoelements, the thermal e.m.f. at the latter temperature. This was done by heating the element up to the melting point of the platinum wire, within a glazed Marquardt porcelain tube, in the region of maximum temperature of a resistance furnace. The furnace was of the carbon tube type.‡ Carbon monoxide around the outside of the porcelain tube protected the furnace from oxidation, and a current of dry air in the inside prevented contamination of the thermoelement. Both wires of the element were enclosed in Marquardt capillaries, leaving only about 2^{mm} of the platinum exposed next to the junction. It was always this portion that melted, the point being marked by a halt of about one minute in the gradual rise in temperature of the element, preceding the formation of a globule and the interruption of the circuit. New Marquardt tubes were used for each determination. Several elements were examined for contamination after the measurement,* and no appreciable amount was found. A vertical section of the furnace is shown in fig. 1.

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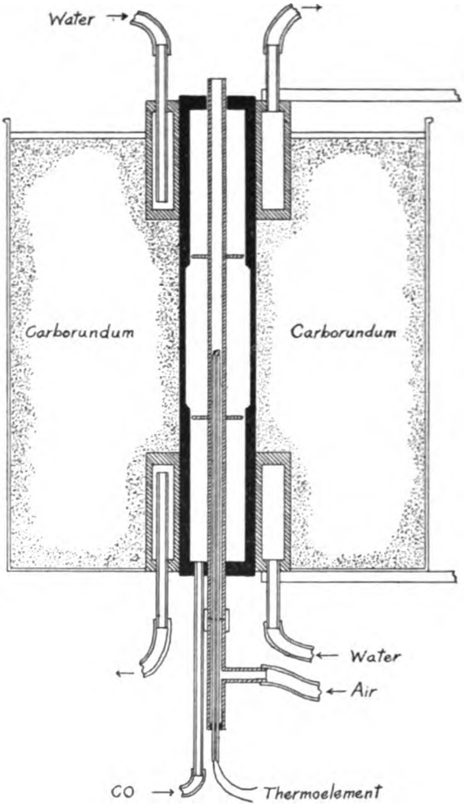
* Loc. cit.

† Loc. cit., p. 161.

‡ S. A. Tucker, Trans. Amer. Electrochem. Soc., xi, 303, 1907.

FIG. 1.



Carbon-tube furnace for melting point of platinum. Scale, 1 : 4.

In Table I are given the experimental results. The values are in microvolts, corrected as discussed in the paper already referred to.† The silver point, being about half way between 0° and platinum, is included in order to indicate the general course of the interpolation curve.

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* Method described in Day and Sosman, loc. cit., p. 116.

† Day and Sosman, loc. cit., p. 115.

With these are included the results obtained by other observers with similar ten per cent rhodium alloys. Harker* measured the e.m.f. at the melting point of the platinum wire in a resistance furnace of refractory oxides. Waidner and Burgess† made similar measurements in connection with their optical determination of the melting point. Their figures, being in terms of the United States legal volt (Clark at 15°= 1·434) have been corrected to the true volt (Clark at 15°= 1·4328). Other investigators (Holborn and Henning,‡ Nernst and von Wartenberg,§ Holborn and Valentiner‖) have measured the melting point of platinum in various ways, but without recording the thermoelectric data.

TABLE I.—THERMAL E.M.F. AT MELTING POINT OF PLATINUM.

Date	No. of Element	Per cent Rh in alloy wire	Silver microvolts	Platinum microvolts
1910—19 Feb....	F	10	9103	18619
24 Feb....	F	10	9103	18613
25 Feb....	Y	10	9139	18695
25 Feb....	Z	10	9018	18487
8 Mar....	J	10	9106	18603
1 Mar....	$I_{1}J$	1	1960	3560
15 Apr....	KJ	5	6495	12444
2 Mar....	$I_{15}J$	15	10375	22308
4 Mar....	$I_{15}J$	15	10375	22310
1905—Harker ...	N. P. L. 3	10	(9084)	18580
" " ...	T. 15	10	(9100)	18693
1907—W. and B.	P 2	10	(9024)	18369
" "	P 3	10	(9040)	18556
" "	S_1	10	(8991)	18250

In general, the curves for all the different 10 per cent elements, both our own and those of other observers, are similar in form, and the divergence of each from the mean increases with increasing temperature. In this connection it should be remarked that the e.m.f. at the palladium point (16140 microvolts) obtained by Holborn and Valentiner with an element whose gold point was 10295, agrees almost exactly with a similar element from our series, with a gold point of 10295 and palladium point of 16143. The disagreement between various observers as to the melting points of these metals is, then, not so much a matter of purity of metals or accuracy of thermoelectric measurements, as it is of the evaluation of these in terms of the nitrogen thermometer.

It is of interest to find what value would be obtained for the melting point of platinum by extrapolating the curves of our own elements, on which we have complete data, using for this purpose the portion of the curve from 1100° to 1550°. A parabola passed through the melting points of copper (1082·6°), diopside (1391·2°) and palladium (1549·2°), gives, in the case of the various 10 per cent elements, values for platinum from 1748° to 1753°; the 1 per cent alloy gives 1750°–1755° (low sensitiveness); the 5 per cent, 1752°; and the 15 per cent, 1755°. The mean is 1752°.

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* J. A. Harker, Proc. Roy. Soc., lxxvi, A, 235–250, 1905.

† C. W. Waidner and G. K. Burgess, Bull. Bur. Standards, iii, 200, 1907.

‡ L. Holborn and F. Henning, Sitzb. Berl. Akad., xii, 311–317, 1905.

§ W. Nernst and H. von Wartenberg, Ber. deut. Phys. Ges., iv, 48–58, 1906.

‖ L. Holborn and S. Valentiner, Ann. Phys., xxii, 1–48, 1907.

In the preceding paper it was pointed out* that the available optical determinations of the melting points of palladium and platinum agree very well as to the *difference* between these two points, although disagreeing as to their absolute value. The mean value of this difference is 206°. Having fixed the palladium point on the nitrogen thermometer, we were able therefore to give the melting point of platinum as 1755° with an estimated accuracy of 5°. The extrapolated value in the preceding paragraph agrees with this figure, 1755°, within the estimated limit of accuracy.

A parallel case to this is found in the values obtained by extrapolating the resistance thermometer above 500°, which come remarkably close to those obtained by the nitrogen thermometer, but which should not on that account be given equal weight with a real measurement. There is no reason to expect that such extrapolation will give true results, for the *downward* extrapolation of the thermoelement equation, and likewise of the resistance thermometer,† goes far astray. The extrapolated values given above for platinum should therefore be considered as merely confirmatory, not as having any independent weight, and we have accordingly, in calculating the interpolation curve for the thermoelement from 1550° to 1750°, used our original value of 1755° for platinum.‡

The summarized temperature scale adopted for present use in this laboratory for the calibration of thermoelements is as follows:

Ice, m. p.	0°
Water, b. p.	100·0° + 0·037 (p–760)
Naphthalene, b. p.	217·7° + 0·057 (p–760)
Benzophenon, b. p.	305·4° + 0·063 (p–760)
Cadmium, m. p.	320·2°
Zinc, m. p.	418·2°
Antimony, m. p. (in CO)	629·2°
Silver, m. p. (in CO)	960·0°
Gold, m. p.	1062·4°
Copper, m. p. (in CO)	1082·6°

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* Day and Sosman, loc. cit., p. 160.

† Travers and Gwyer, Zeitschr. phys. Chem., lii, 437, 1905.

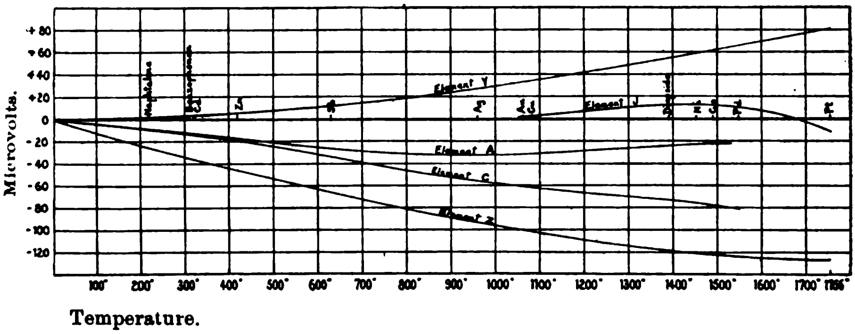
‡ In view of these facts, it is evident that Harker's figure, 1710°, obtained by extrapolating the curves of a number of platinum-rhodium and platin-iridium thermoelements from 1100° up to their melting points, has little or no value as an estimate of the melting point of platinum.

Diopside, m. p.	1391·2°
Nickel, m. p. (in N_2)	1452·3°
Cobalt, m. p. (in N_2)	1489·8°
Palladium, m. p.	1549·2°
Platinum, m. p.	1755°

4. *Interpolation.*

For interpolation between these points we may use either an empirical equation or series of equations, or we may plot the temperatures and microvolts and draw a smooth curve through the points. The results of one method have no better claim to accuracy than the results of the other, for an empirical equation is essentially nothing but an imaginary curved ruler. A plotted curve on a scale large enough to get the requisite accuracy of reading would, however, take a sheet at least 30 feet square. But if instead of plotting microvolts directly against degrees, we plot the *deviation* from the straight line, $e = 10\,t$, the sheet required is reduced to about 3 feet square. If further, we plot the deviations of each element from an *arbitrary standard curve*, instead of the deviations from a straight line, the usual $50^{cm} \times 40^{cm}$ sheet is ample.

FIG. 2.



Deviation of typical thermoelements from standard curve.

The figures of Table II represent such a curve, which lies very close to the actual curve for the standard thermoelement E used in the work on the nitrogen thermometer. It is made up of several parabolas connected by transition curves. The deviations of various other elements, in use in the laboratory, from this standard are plotted in fig. 2. These curves are obtained by plotting the differences between the reading of the element and that of the assumed standard at each calibration point.

An example will serve to make clear the method of converting microvolts into degrees with this table and curve. It is desired to find the temperature corresponding to a reading of 8931 microvolts on element Z. It is evident from the table that the temperature is in the neighborhood of 950°. At about this temperature, element Z reads 92 microvolts below the assumed standard; adding 92 microvolts to 8931 gives 9023 microvolts as the corresponding standard reading, and this by interpolation in the table gives 952·3°. The tenths, of course, mean little in absolute value; but temperature *differences*, in case measurements are made with similar elements under similar conditions, can often be obtained to tenths of a degree.

The use of this table and deviation-curve avoids the calculation and recalculation of thermoelement curves and the tabulation of their readings. If the calibration of an element changes by a few microvolts, the deviation-curve is merely raised or lowered by a corresponding amount. If the value adopted for one of the calibration points is changed, the corresponding reading in microvolts of the assumed standard is also changed, and all the deviation-curves take a slightly different course in the neighborhood of that point. The table and curves make it possible, furthermore, to estimate temperatures (with an accuracy of perhaps 5°) with a new thermoelement, by simply calibrating it at, say, two points such as silver and diopside, and thus locating it among the family of deviation-curves.

5. *Relation of Thermal E.M.F. to Composition.*

In the course of the work on the nitrogen thermometer, the standard 10 per cent elements were compared with elements whose alloy wires contained 1 per cent and 15 per cent rhodium. The e.m.f. of the 20 per cent alloy, of which the bulb was made, was determined by two methods,* for the purpose of evaluating the differential readings on the nitrogen thermometer bulb. To make the series more complete, a 5 per cent alloy was obtained from Heraeus and its readings against pure platinum were compared with the standards.

A similar series of comparisons was made in 1892 by Holborn and Wien,† using alloys with 9, 10, 11, 15, 20, 30, 40, and 100 per cent rhodium. This work was done, however, just at the beginning of the careful work of Mylius on the separation of the platinum metals, and the alloys then available were not pure. In the lower percentage alloys, different elements of the same nominal composition gave e.m.f.'s differing by 10 per cent or more, and varying differently with temperature. In the higher percentages, the e.m.f. varies little with the composition, and the results have therefore

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* Day and Sosman, loc. cit., p. 119.

† L. Holborn and W. Wien, Über die Messung hoher Temperaturen. Ann. Phys., xlvii, 107-134, 1892.

TABLE II.—STANDARD CURVE OF ELEMENT PT: (90 PT 10 RH) FROM 0° TO 1755°.

t	e	Diff.	t	e	Diff.	t	e	Diff.
0		55	300	2315	92	580	5026	101
10	55	57	*305·4 Benzo.*	*2365*		590	5127	102
20	112	60	310	2407	93	600	5229	102
30	172	62	320	2500	93	610	5331	103
40	234	63	*320·2 Cd*	*2502*		620	5434	103
50	297	65	330	2593	93	*629·2 Sb*	*5529*	
60	362	67	340	2687	94	630	5537	103
70	429	69	350	2781	94	640	5640	104
80	498	71	360	2875	94	650	5744	104
90	569	72	370	2969	95	660	5848	104
100	641	73	380	3064	95	670	5952	104
110	714	75	390	3159	95	680	6056	105
120	789	77	400	3254	96	690	6161	105
130	866	78	410	3350	96	700	6266	105
140	944	79	*418·2 Zn*	*3429*		710	6371	106
150	1023	80	420	3446	96	720	6477	106
160	1103	81	430	3542	97	730	6583	106
170	1184	82	440	3639	97	740	6689	106
180	1266	83	450	3736	97	750	6795	107
190	1349	84	460	3833	98	760	6902	107
200	1433	85	470	3931	98	770	7009	108
210	1518		480	4029	98	780	7117	108
217·7 Napht.	*1584*	86	490	4127	99	790	7225	108
220	1604	86	500	4226	99	800	7333	108
230	1690	87	510	4325	99	810	7441	109
240	1777	88	520	4424	100	820	7550	109
250	1865	89	530	4524	100	830	7659	110
260	1954	89	540	4624	100	840	7769	110
270	2043	90	550	4724	100	850	7879	110
280	2133	91	560	4824	101	860	7989	111
290	2224	91	570	4925	101	870	8100	111

TABLE II.—STANDARD CURVE OF ELEMENT PT: (90 PT 10 RH) FROM 0° TO 1755°.—*Concluded.*

t		e	Diff.	t		e	Diff.	t		e	Diff.
880		8211	111	1170		11572	120	1470		15183	121
890		8322	112	1180		11692	120	1480		15304	121
900		8434	112	1190		11812	120	*1489·8*	*Co*	*15423*	
910		8546	112	1200		11932	120	1490		15425	121
920		8658	113	1210		12052	120	1500		15546	120
930		8771	113	1220		12172	120	1510		15666	121
940		8884	113	1230		12292	120	1520		15787	121
950		8997	114	1240		12412	120	1530		15908	121
960		9111	114	1250		12532	120	1540		16029	121
960·0	*Ag*	*9111*		1260		12652	120	*1549·2*	*Pd*	*16140*	
970		9225	114	1270		12772	120	1550		16150	120
980		9339	115	1280		12892	120	1560		16270	121
990		9454	115	1290		13012	120	1570		16491	121
1000		9569	116	1300		13132	120	1580		16512	120
1010		9685	116	1310		18252	120	1590		16632	121
1020		9801	116	1320		13372	120	1600		16753	120
1030		9917	117	1330		13492	120	1610		16873	120
1040		10034	117	1340		13612	121	1620		17093	120
1050		10151	117	1350		18733	121	1630		17113	120
1060		10268	118	1360		13854	121	1640		17233	120
1062·4	*Au*	*10296*		1370		18975	120	1650		17353	120
1070		10386	118	1380		14095	121	1660		17473	120
1080		10504	118	1390		14216	121	1670		17593	120
1082·6	*Cu*	*10535*		*1391·2*	*Diops.*	*14231*		1680		17713	120
1090		10622	118	1400		14337	121	1690		17833	120
1100		10740	118	1410		14458	121	1700		17953	120
1110		10858	119	1420		14579	120	1710		18073	120
1120		10977	119	1430		14699	121	1720		18193	120
1130		11096	119	1440		14820	121	1730		18313	120
1140		11215	119	1450		14941	121	1740		18433	120
1150		11334	119	*1452·3*	*Ni*	*14969*		1750		18553	120
1160		11453	119	1460		15062	121	*1755·*	*Pt*	*18613*	

some value in indicating the course of the curve of e.m.f. and composition. The data have been corrected to our temperature scale, and also for the difference in e.m.f. standards.

Holborn and Day* in 1899 obtained the e.m.f. of pure platinum against two samples of pure rhodium up to 1300°. The data have been corrected to correspond to our temperature scale.

Waidner and Burgess† measured the e.m.f. of the 10 per cent against the 20 per cent alloy, using two samples, at various points up to 1755°. The addition of this value to the e.m.f. of the 10 per cent alloy against pure platinum gives an independent check on our direct measurements with the 20 per cent alloy. As appears on the curves in fig. 4, the agreement is very good.

TABLE III.—THERMAL E.M.F. OF PURE PLATINUM AGAINST PLATINUM-RHODIUM ALLOYS, IN MILLIVOLTS.

t	1%	5%	10%			15%	20%	30%‡	40%‡	100%§
			Low	High	Standard					
100°	0·21	0·55	0·63	0·64	0·64	0·65	....	....	....	0·65
200	0·42	1·18	1·41	1·43	1·43	1·50	....	....	....	1·51
300	0·63	1·85	2·28	2·32	2·32	2·41		2·34	2·45	2·57
400	0·84	2·53	3·21	3·26	3·25	3·45	3·50	3·50	3·64	3·76
500	1·05	3·22	4·17	4·23	4·23	4·55	4·60	4·74	4·93	5·08
600	1·25	3·92	5·16	5·24	5·23	5·71	5·83	6·06	6·31	6·55
700	1·45	4·62	6·19	6·28	6·27	6·94	7·18	7·49	7·80	8·14
800	1·65	5·33	7·25	7·35	7·33	8·23	8·60	9·01	9·37	9·87
900	1·85	6·05	8·35	8·46	8·43	9·57	10·09	10·67	11·09	11·74
1000	2·05	6·79	9·47	9·60	9·57	10·96	11·65	12·42	12·94	13·74
1100	2·25	7·53	10·64	10·77	10·74	12·40	13·29	14·33	14·99	15·87
1200	2·45	8·29	11·82	11·97	11·93	13·87	14·96	16·39	17·13	18·10
1300	2·65	9·06	13·02	13·18	13·13	15·38	16·65	18·51	19·51	20·46
1400	2·86	9·82	14·22	14·39	14·34	16·89	18·39	20·67	21·73	....
1500	3·06	10·56	15·43	15·61	15·55	18·41	20·15	....	....	....
1600	3·26	11·31	16·63	16·82	16·75	19·94	21·90	....	....	....
1700	3·46	12·05	17·83	18·03	17·95	21·47	23·65	....	....	....
1755	3·56	12·44	18·49	18·70	18·61	22·31	24·55	....	....	....

The summarized data are given in Table III. For the 10 per cent alloy three values are given: first, the lowest-reading of the twelve elements used with the nitrogen thermometer; second, the highest-reading; and third, the standard element E.

The frequent comparisons of the platinum and rhodium wires of the standard 10 per cent elements during the work on the nitrogen thermometer, show that the differences among them are due partly to the platinum wire and partly to the alloy. Element Z, for instance, reads lower than E chiefly because the platinum wire of Z, is more impure than that of E; the effect of this impurity is partly neutralized by an apparently larger amount of rhodium in the alloy wire. This appears from the data in the table below, which show comparisons between several typical 10 per cent elements. The purest platinum appears to be that of J. If the thermoelectric effect of rhodium is proportional to its percentage from 0 to 1 per cent, then about 0·05 per cent rhodium in the platinum wire would be sufficient to produce the difference between Z and E. The data are in microvolts.

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* Thermoelectricity in Certain Metals. this Journal (4). viii, 303–8, 1899; Ann. Phys. (4), ii, 522, 1900; Sitzb. Berl. Akad., xxxvi, 691–5, 1899.

† Bur. Bull. Standards, iii, 200, 1907.

‡ Holborn and Wien, 1892, loc. cit.

§ Holborn and Day, mean value, 1899, loc. cit.

Element	E.M.F. of Pt wire against Pt of E at 1500°	E.M.F. of Rh wire against Rh of E at 1500°	Difference between elements
Y	+ 12	+75	+ 63
Z	+177	+67	−110
A	+ 75	+47	− 28
F	+ 7	+ 1	− 6
J	− 9	+ 1	+ 10

The data of Table III are plotted in fig. 3, which shows the relation between temperature and thermal e.m.f. for various alloys. The 30 per cent and 40 per cent curves represent the data of Holborn and Wien. The curve for pure rhodium represents the mean of the two samples of Holborn and Day. There is no indication of a break in any of the curves, over the entire range of temperature.

In fig. 4 the data of Table III are plotted to show the relation of the thermal e.m.f. at various constant temperatures to the composition of the alloy wire, the cold junction being in every case at 0°. At all temperatures the e.m.f. increases very rapidly with the first additions of rhodium, and at 20 per cent the value has already reached 81 to 93 per cent of the e.m.f. of platinum against pure rhodium.

The thermoelectric power, or rate of change of e.m.f. with temperature, $\frac{de}{dt}$, is plotted in fig. 5 against the atomic concentration of the alloy. The values are in microvolts, against pure platinum. The curves for all temperatures are similar in form and approach the curve for 1755° as an envelope.

In a recent study of the thermoelectric properties at low temperatures of the alloys of tellurium with antimony, tin, and bismuth, and of antimony with silver, Haken* comes to the conclusion that a thermoelectric curve of the form of those in fig. 5 accompanies the formation of a solid solution between the end components, while compounds are marked by sharp maxima or minima. The thermoelectric curves of the systems

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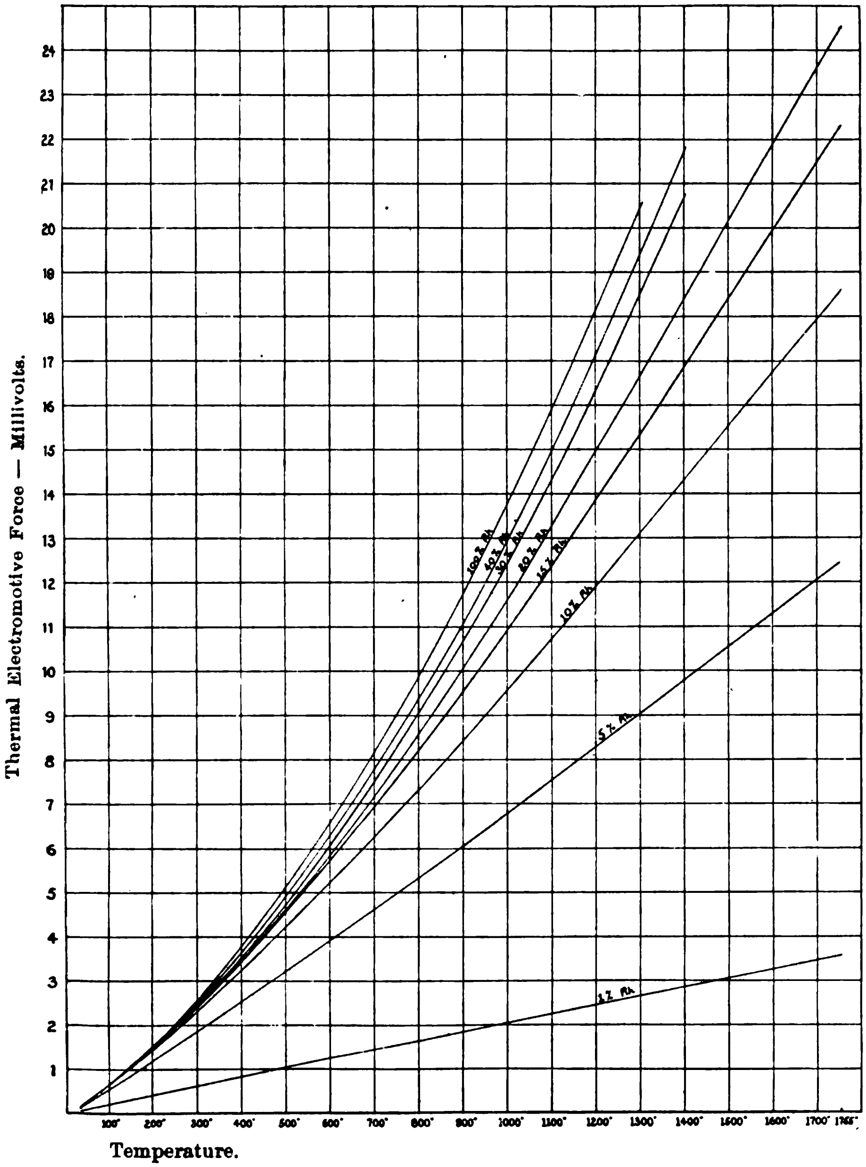
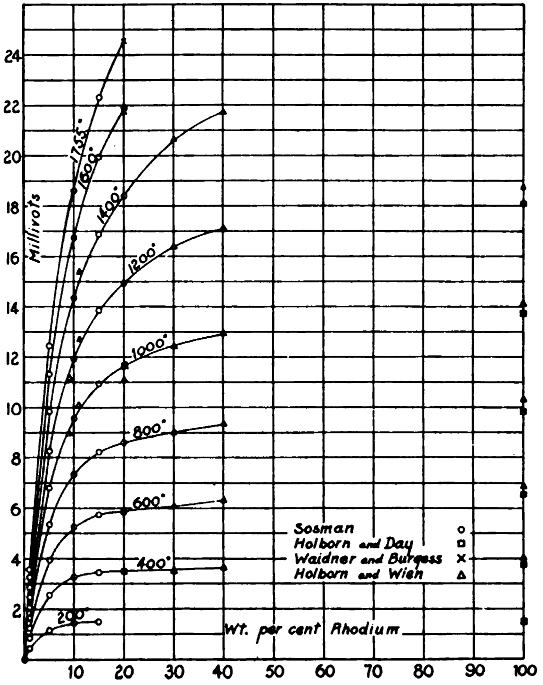
* Verh. Deutsch. Phys. Ges., xii, 229–39, 1910.

Fig. 3.



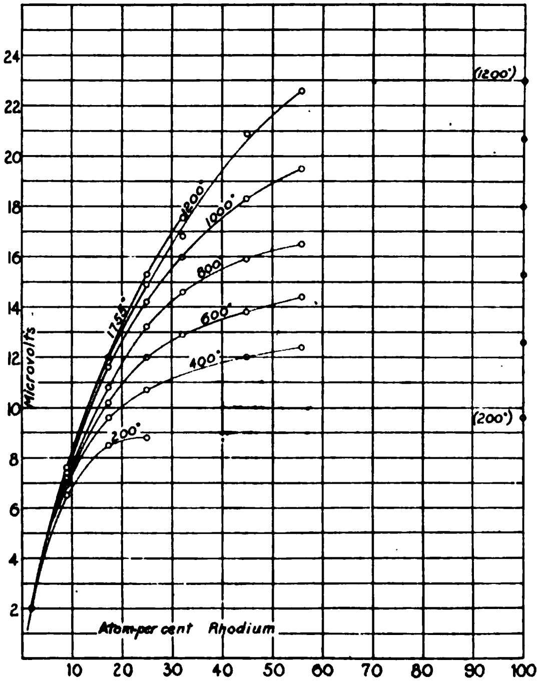
Relation of temperature to thermal electromotive force of platinum against platinum-rhodium alloys.

Fig. 4.



Relation of thermal electromotive force, e, to composition of platinum-rhodium alloys.

Fig. 5.



Relation of $\frac{de}{dt}$, thermoelectric power against platinum, to atomic composition.

copper-cobalt, by Reichardt;* copper-nickel, by Feussner and Lindeck; † and silver-zinc, by Puschin and Maximenko,‡ show a similar relationship between the form of the curve and the constitution of the alloy.

The alloys of platinum and rhodium have not been studied microscopically or thermally, but measurements in our carbon-tube furnace showed that the melting points of the 1 per cent and 5 per cent alloys are higher than 1755°. The melting point of the 10 per cent alloy is given by von Wartenberg § as 1830°, and of pure rhodium as 1940°. It is very probable, therefore, that platinum and rhodium form solid solutions at least as far as 55 atomic per cent rhodium, with no compounds, over the range of temperature covered by the data.

6. *Summary.*

1. In continuation of the recent work from the Geophysical Laboratory on the nitrogen thermometer from zinc to palladium the interpolation curve of the thermoelement Pt: (90 Pt 10Rh) has been extended downward to 0° and upward to the melting point of platinum, 1755°. The standard scale of temperatures adopted is given on page 6.
2. The value of the melting point of platinum obtained by extrapolation of the curves of thermoelements with from 1 to 15 per cent rhodium confirms the value 1755° within the estimated limit of 5°.
3. A simple method of interpolating temperatures with the 10 per cent thermoelement by means of a standard curve (Table II, p. 9) and deviation curves (p. 7) is described.
4. The variation of thermal e.m.f. with the temperature and composition of the alloy wire is shown graphically in figs. 3 and 4, pages 13 and 14. The variation, both with temperature and with composition, is, within the limits of error, continuous over the entire range studied.
5. The variation of thermoelectric power, $\frac{de}{dt}$, with the temperature and composition of alloys of platinum and rhodium, is shown graphically in fig. 5, page 14. The data indicate the formation of solid solutions, but no compounds, from 0 to 55 atomic per cent of rhodium.

Geophysical Laboratory,
Carnegie Institution of Washington,
Washington, D. C., April 30, 1910.

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* Ann. Phys. (4), vi, 832–55, 1901.
† Wiss. Abh. Phys.-Tech. Reichsanst., ii, 1895.
‡ Jour. Russ. Phys. Chem. Ges., xli, 500–524, 1909.
§ Verh. Deutsch. Phys. Ges., xii, 121-127, 1910.

ART. II.—*On some Remarkable Twins of Atacamite and on some other Copper Minerals from Collahurasi, Tarapaca, Chili;** by W. E. FORD.

SOME time ago a suite of copper minerals from Collahurasi, Chili, was presented to the Brush Collection by Mr. Ernest Schernikow of New York City. They included the following rare species: atacamite, brochantite, olivenite, clinoclasite, and conichalcite. The atacamite and the brochantite occurred in crystals and in considerable quantity, so that they offered excellent opportunities for investigation.

Atacamite.—This mineral was found in crystalline masses made up for the most part of quite small crystals, but at times showing individuals four or five millimeters in length. These crystals on examination proved to be unusually interesting. The forms present were few, being *m* (110), *x* (140), *b* (010), *e* (011), *r* (111) and *n* (121). The majority of the crystals showed only the brachypinacoid, unit prism, and dome, illustrated in figure 1. The pyramids *r* and *n* and the prism *x* were only observed on a few individuals and then only as small truncations, as shown in figure 2. The interest in the crystals lay, however, in the constant and unusual twinning that they showed. The law of twinning is new to atacamite and in some ways proved very puzzling and difficult to explain, but

FIG. 1.

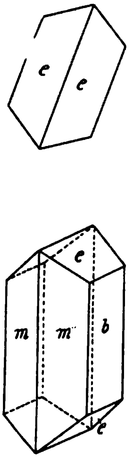


FIG. 2.

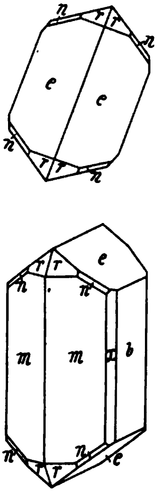
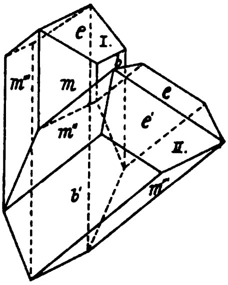


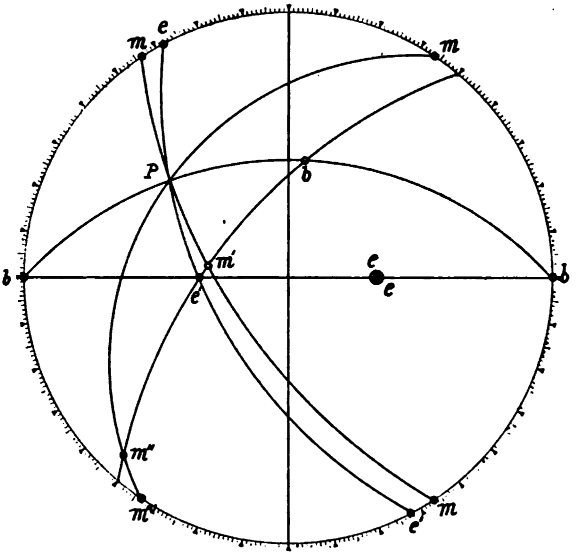
FIG. 3.



the close agreement between the measured and calculated angles, as shown in the tables below, leaves no doubt that it has at least been correctly formulated.

The law of twinning may be stated as follows: One of the *e* planes of the twin individual is always parallel to one of the *e* faces of the individual in normal position. This is readily seen on inspection of the crystals, for one brachydome face of the twin always "flashes" with one of the dome faces of the normal individual. Further, the twinned individual has been turned on the pole to *e*(011) as if on a twinning axis through such an angle that the second *e* face of the twin falls in the prism zone of the crystal in normal position. These relations can be best explained by use of figure 3, drawn, not from a crystal, but rather to illustrate the law. Face *e* of the crystal in twin position (No. II) is parallel to *e* of the individual in normal position (No. I), while *e*′ of No. II falls in the same zone as the prism and pinacoid faces of the vertical crystal. These facts were proven when the twin crystals were placed upon the reflection goniometer. The signals from the *e* faces of the two individuals coincided with each other, and the signal from *e*′ of No. II fell in the same zone as the prism faces of No. I. This was found to be true on all the crystals measured, with only such slight variations as the occasional rather

FIG. 4.



indifferent quality of the faces could easily account for. The relations existing between the two individuals is shown in the stereographic projection, figure 4.

In order to bring the two individuals into their respective positions, i. e., *e'* of No. II into the prism zone of No. I, we have to conceive of individual No. II as being turned about the pole of *e* (011) as an axis through an arc of 112° 40′. This is the fact that makes these twins unusual and difficult to explain. The arc of revolution of a twin crystal about a twinning axis is usually 180° or sometimes 120°. On account of this peculiarity we cannot consider, at least in the usual sense, either the plane *e*, although it is common to the two individuals, as a twinning plane nor its pole as a twinning axis. The plane whose pole is lettered P on the stereographic projection, and which is shown as the plane of junction of the two individuals in figure 3, would answer to the ordinary definition for a twinning plane. The twinned half of the crystal could be obtained from the normal half by reflection over this plane, as is shown in the stereographic projection, for upon a great circle drawn from any face of individual No I through the pole P will be found at an equal angular distance on the other side of P, the corresponding face of the twinned individual, No. II. But this plane P does not correspond in its position to any crystal face on atacamite, falling nearest to the possible pyramid $(4\bar{7}5)$. The proof of the law of twinning as stated lies in the following tables of measured and calculated angles. The crystals were measured on both the two-circle and one-circle goniometers, the angles obtained on each being given.

1. Angles measured on the two-circle goniometer giving the position of the faces of the twin individual.

Faces of	Measured				Calculated	
No. II	φ	Average	ρ	Average	φ	ρ
e			36° 58′*	36° 50′	0° 0′	36° 55½′
			36 50			
			37 16			
			36 45			
			36 24			
e'	62° 29′*	62° 46′	90° 1′*	90° 6′	62° 25′	90° 0′
	63 1		90 38			
	62 12		90 21			
	63 22		89 24			
m	8° 59′*	10° 20′	34° 31′*	33° 24′	8° 47′	33° 57′
	8 44		31 44			
	11 38		34 1			
	12 1		33 21			

Faces of	Measured				Calculated	
No. II	φ	Average	ρ	Average	φ	ρ
m'	47° 45'*	46° 31'	83° 56'*	83° 49'	47° 1½'	84° 31'
	47 38		84 8			
	45 25		83 46			
	46 20		82 58			
	46 31		85 2			
	46 3		84 54			
	46 12		84 2			
b	80° 48'*	80° 29'	48° 35'	47° 51'	81° 9'	48° 17
	80° 9'		47° 7'			

2. Angles measured on a one-circle goniometer between faces of individuals I and II.

	Measured	Average	Calculated
e' of No. I ∧ *e'* of No. II	106° 24'	106° 11'	106° 10'
	105 54		
	106 23		
	106 3		
m of No. I ∧ *e'* of No. II	5° 44'	5° 53'	5° 53½'
	6 20		
	5 54		
	5 36		
m''' of No. I ∧ *m''* of No. II	10° 39'	11° 1'	10° 57'
	11 17		
	10 42		
	11 17		
m of No. I ∧ *m''* of No. II	67° 56½'	67° 58'	67° 54'
	68 1		
m''' of No. I ∧ *m'* of No. II	76° 56	76° 42'	76° 29'
	76 6		
	76 59		
	76 50		

The above tables give all the measured angles on the different crystals without regard to the quality of the faces and the consequent authority of the angles. In general, however, the average values of the angles of the different series are reasonably close to the calculated angles. In the case of the table of the measurements made on the two-circle goniometer the angle, derived from the measurement of the best crystal and the one which permitted of the most accurate adjustment on the goniometer, is given first in each list and is further marked by an asterisk. The agreement between these angles and the corresponding theoretical values is quite close. The widest variation between the measured and the calculated angles is to be found in the case of the faces in the prism zone, and with these faces particularly in the case of the ϕ angles. This is a result to be expected from the usual rather poor quality of the prism faces and from the fact that they are frequently vertically striated.

It will be noticed that in the case of the one-circle goniometer measurements the agreement between the measured and the calculated angles is much closer and in general is very satisfactory. This is as would be expected, since with these small crystals having not the best of faces the adjustment of a crystal upon the two-circle goniometer is difficult and can only be approximate at the best, and consequently the angles measured upon it have not as great an authority as those made upon the one-circle instrument where the adjustment is made for each measurement. Considering, however, all the measurements, their agreement with the theoretical angles is sufficiently exact to prove without doubt that the law of twinning has been correctly stated.

The author does not know of any case of twinning strictly analogous to the one outlined above, and he does not offer any elaborate explanation or theory to account for the peculiarities shown by these twins. An interesting and probably significant fact is that, when in twin position, the faces of individual No. II lie for the most part within a few degrees, at least, of the faces of the normal individual, No. I. This is clearly brought out in the stereographic projection, figure 4, where *e′* of No. II lies near *m* of No. I; *m″* of II near *m‴* of I; *m′* of II near *e′* of I; and *b′* of II falls near the macrodome zone of I. It would seem here as if we had a case of twinning in which the position of the twin individual was controlled rather by parallelism of a prominent face and by zonal relations between the two individuals than by the presence of a common twinning plane or axis. The plane P, which if a possible crystal plane would be considered as the twinning plane, may be regarded as a composition or accommodation plane similar in a way to the rhombic section found in the plagioclase feldspars when they twin according to the pericline law.

That all regular intergrowths of crystals do not obey the ordinary laws of twinning has been recognized for some time.* These intergrowths are not accidental in character, but obey laws that can be definitely formulated; they are to be found repeatedly on different specimens and must be included in any complete discussion of twinning. Goldschmidt has recently attempted to include these unusual intergrowths in a new classification of twins and has given various names to the new groups he has formed, such as "Heterozwillinge," "Einflächige Verwachsung," "Einzonige Verwachsung."[*] It is to be expected, as attention is called to these twins of lower symmetry, that more examples will be discovered and still other groups formed. In fact the twins described in this paper do not seem to exactly fit into any of the groups in Goldschmidt's scheme, resembling most nearly, however, his group of "hetero-twins." A hetero-twin of orthoclase recently described by Paul and Goldschmidt[†] is in some respects similar to these twins of atacamite. The law governing the orthoclase twin is stated as follows: the face *c* (001) of No. II is parallel with *b* (010) of No. I; the zone *c* (001)–*m* (110) of No. II corresponds with zone *b* (010)–*c* (001) of No. I, and face *b* (010) of No. II falls in the zone *c* (001)–*y* (201) of No. 1. Here we have in the two individuals a parallelism of two unlike faces, two unlike zones falling together and a prominent face of one individual falling in a prominent zone of the other. In the case of the atacamite twins we have, on the other hand, two similar faces in parallel position and a prominent face on No. II lying in a prominent zone of No. I, and in general the faces of No. II lying near to faces or zones of No. I.

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* See Goldschmidt, Zs. Kr. xxx, 254, 1898; xliii, 347, 1907.

FIG. 5.

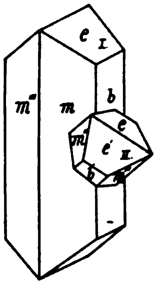


FIG. 6.

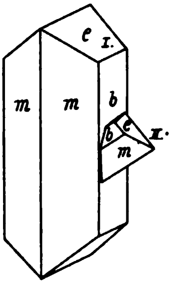
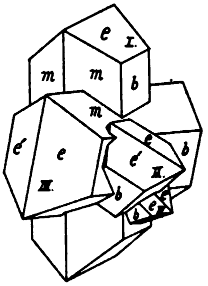


FIG. 7.



The twin crystals are of two types. The first, which is illustrated in figures 5 to 7, is of an interpenetration type where one individual grows through another or projects from it. Usually in this type one individual is much larger than the other, and the smaller is seen in the group of faces at one of its ends projecting from the side of the first. Such a crystal is shown in figure 5. Of such an intergrowth there can be two sorts, depending upon whether the twin individual has been turned toward the front or the back of the one in normal position. Figure 6 shows such a twin with No. II projecting from the back of No. I. These twins appear sometimes in very complex groups, one individual being twinned upon the first, a third being in twin position in regard to the second, etc. Such a complex group is represented in figure 7, No. II being in twin position in respect to No. I, while No. III is in twin position in respect to No. II, *e* of III being parallel to *e'* of II, etc.

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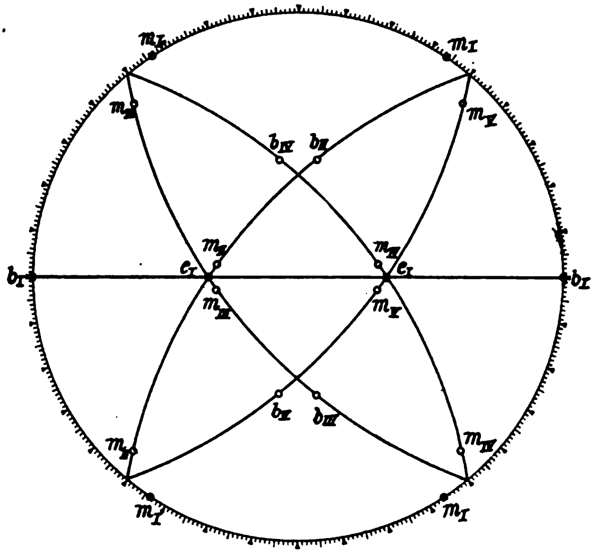
[*] Zs. Kr., xliii, 582, 1907.

[†] Zs. Kr., xlv, 471, 1909.

The second type of twin crystals, although governed by the same law, is very different in habit. It consists of a normal individual having a rather stout development, with its dome faces at either end nearly if not entirely covered by four individuals in twin position. Two of these twin individuals have one of their *e* faces parallel to one of the planes of the crystal in normal position, one twin being revolved toward the front and the other toward the back. The other two twin individuals have a similar relationship and arrangement except one of their *e* faces is parallel to the second *e* face of the normal crystal. These twinned individuals usually show only the faces of the prism and the brachypinacoid, which, lying on the top of the normal crystal, form shallow troughs running in the direction of the brachyaxis on either side above the position of its dome faces. Occasionally *e* faces of the twins are found either at the side forming a projection over *b* (010) of the normal crystal or sometimes in slight reëntrant angles along the crest of the crystal. These relations are shown on the stereographic projection, figure 8, which gives the forms of the crystal in normal position and the prism and pinacoid faces of the four different twin posi-

Fig. 8.



tions, II, III, IV, and V. A crystal of this type is illustrated in figure 9, where the four twin individuals do not entirely cover up the dome faces of the normal crystal. This figure also shows the *e* face common to twins IV and V above the *b* face of the normal crystal. At times the faces in twin position completely envelope the ends of the normal crystal, allowing only the faces of its prism zone to show. A doubly terminated crystal of this type is shown in figure 10. Figure 11 is the same as figure 10 with the lines of the back faces showing in order to assist in forming a mental picture of these strange twin groups. In addition to groups such as figured there are much more complicated ones in which both types of twins are found with bewildering relations to each other.

Fig. 9.

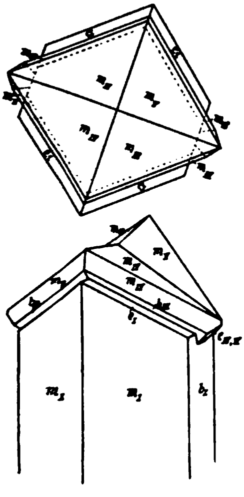


Fig. 10.

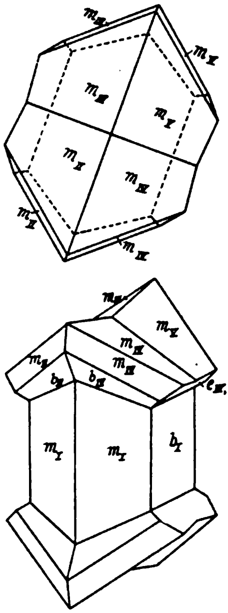
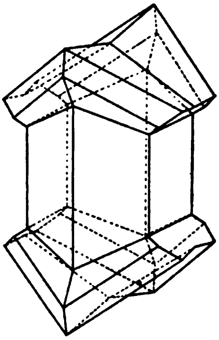


Fig. 11.



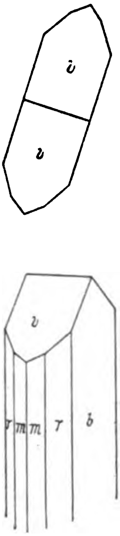
An analysis was made of the atacamite crystals which agreed closely with the theoretical composition of the mineral as shown below.

		Theory
Cl	16·55	16·6
Cu	14·82	14·9
CuO	56·01	55·8
H_2O	12·69	12·7
Total	100·07	100·0

Brochantite.—Brochantite was the most common mineral observed on the specimens. It occurs generally in slender prismatic crystals that interlace and cross each other to form granular crystalline masses. Occasionally a crystal with good faces was observed that could be measured. The following forms were identified: *b* (010), *m* (110), *r* (120), and *v* (101), and their characteristic development is shown in figure 12. In addition to this type of occurrence, brochantite was observed in very slender, almost capillary, prisms arranged in radiating tufts on the surface of the gangue material. With its transparent, bright green color, this variety makes very striking and beautiful specimens. A quantitative analysis of these slender crystals was carried far enough to establish their identity with brochantite. An analysis of the type of material first described was carried to completion. The material analyzed was of ideal purity, and the results agree very closely with the theoretical values. The results of the analysis follow:

	I	II	Average	Theory
CuO	70·41	70·16	70·29	70·37
SO_3	17·51	17·59	17·54	17·69
H_2O	11·91	12·01	11·96	11·94
			99·79	100·00

FIG. 12.



Olivenite occurs on the specimens as slender to acicular prismatic crystals of light to dark olive-green color. The mineral gave the appropriate tests for olivenite, and one crystal was found which had terminal planes sufficiently good to permit of decisive measurements being made. The prism zone of the crystals was always deeply striated, and terminal planes were only rarely observed.

Clinoclasite was observed on only a few specimens, and then in microscopic crystals. It was identified by its blue-black color and the blowpipe tests that it gave. Conichalcite was found very sparingly in the characteristic emerald-green globular form. Other copper minerals in small amount were observed, some of which could not be positively identified with any known species but which occurred in too small an amount to permit of investigation.

Mineralogical Laboratory of the Sheffield Scientific School
of Yale University, New Haven, Conn.,
February, 1910.

Art. III.—*Crustal Warping in the Temagami-Temiskaming District, Ontario;* by L. V. Pirsson.*

The gradual rising of the great Ontarian shield, upon whose southwestern flank the great lakes are being slowly tilted to the southwestward, presents a geologic problem of primary importance. We may reasonably expect that fuller knowledge concerning it will throw much light on secular continental movements.

This tilting and the various phenomena to which it has given rise have been the subjects of study by various geologists, particularly Gilbert and Taylor, whose results have been published in a notable series of articles. The latter has especially studied the sequence of events arising along the north shores of the Great Lakes from their southward canting, and, in his paper on the former Lake Algonquin stage of the lake system, he presents a map upon which the node lines, or axes of tilting, are given.† It is of great importance that this work should be carried to the northward, and especially to the northeast, so that ultimately the crest and extent of the rising shield may be determined. So far not much work in this direction has been undertaken with this object in view, and in this brief paper the writer desires to point out a region whose topographic features appear to offer much of interest and significance in connection with this matter. His attention was first called to it in the summer of 1907, on a visit to the mining region of Cobalt, during which Lake Temagami was traversed and Lake Temiskaming and the Ottawa valley descended. No detailed studies were carried out, but the observations made en route on journeys lasting a couple of weeks in this area aroused his interest in it, and this has been deepened by a study of what has been written upon it, and especially by the excellent report and geologic maps of Barlow‡ and of the Provincial geologists on the mining district. The facts given in this article are taken mostly from these sources, supplemented in a few cases by original observations.

Lake Temiskaming.—This lake is nearly 70 miles long from the point where the River des Quinzes enters it to the outlet at the head of the Long Sault Rapids. While in the upper portion it is several miles wide, this width soon diminishes and the greater part of the lower portion is not over a mile broad, or is even less; in some stretches it is not wider than the Ottawa River to which it gives rise. There is a difference of water level between the head and foot, at times, of one or two feet and this gives a distinct current through the lake, which at the narrower constrictions becomes quite pronounced. The general direction of the lake is south-southeast. While the upper part of the valley occupied by the lake is more open, the greater part, where the lake is narrow, is a deep trench cut in the gneisses of the old upland. Thus from the shores rise abruptly bold rocky hills with heights ranging from 350 to 600 feet, which in many places pass into towering cliffs. Thus the aspect of the lake is like that of a fiord, and it is in truth a miniature Saguenay. At the same time, considering its narrowness, the lake is remarkably deep. From the Opemika Narrows at the point marked A on the map, Barlow found that the depth gradually increased until it reached 470 feet near the mouth of the Kipiwa* River. This is near the middle of

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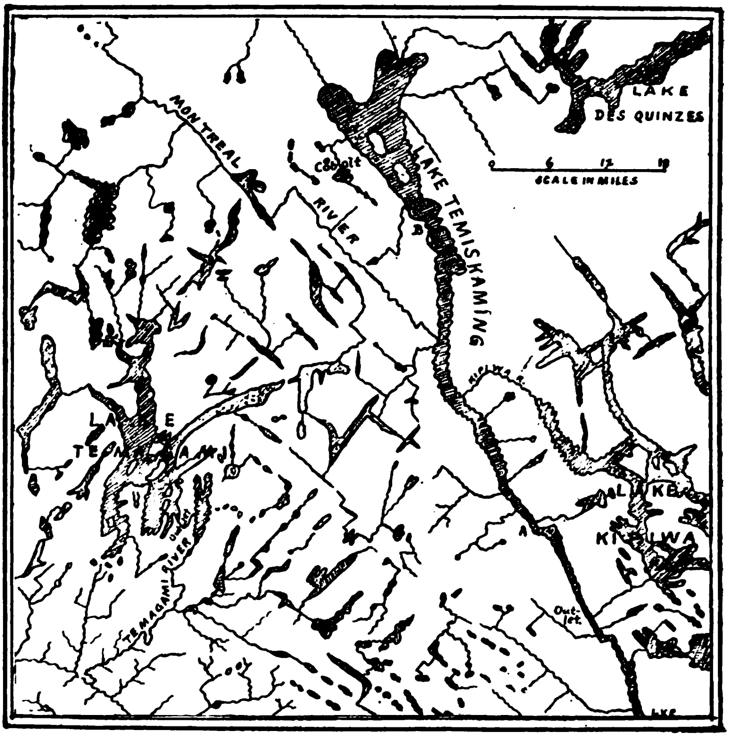
* Abstract of a paper given before the Yale Geological Club, April, 1909.

† F. B. Taylor, Amer. Geol., vol. xv, p. 116. 1895.

‡ Ann. Rep. Geol. Surv. of Can., vol. x, 1897, Rep. I.

Fig. 1.



Drainage map of the Temagami-Temiskaming Region.

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* This name is spelled in a variety of ways; even on the same official map more than one appears. The spelling selected seems the simplest and to express the sounds as the inhabitants pronounce it; the writer, however, disclaims any attempt to fix usage.

the lake; from here it gradually shallows and opposite the mouth of Montreal River is 350 feet deep. At the point B on the map, old Fort Narrows, there is a very marked contraction, owing to a heavy deposit of sand and gravel in the trench at this place. The depth on this is perhaps 50 feet and the lake again deepens to the north but does not reach the great depths of the lower part. It is also to be noted that where these great depths were obtained it was not only in the middle of the channel but close up to either shore.

From what has been stated it will be seen that the total depth of the trench, or rather canyon occupied by the lake, from the surface of the old upland to the lake bottom, is about 1000 feet at the deepest point. shallowing gradually either way, north and south. At the deepest point the former canyon is about one-half filled with water.

What is the origin of this lake? For one of its size and nature in this region three possibilities present themselves: it may be a rock basin cut by the ice sheet; it may be a river valley dammed by glacial drift, or it may be a warped valley. In regard to the first, since the general direction of flow of the ice sheet was toward the southwest or more accurately S. 14° W., as given by Barlow, it is inconceivable that it could have cut such a deep and narrow gorge transverse to its direction of flow. Barlow's list of glacial striæ shows, as might be expected, that in the upper, wider portion of the lake valley the topography exercised enough control to produce an undercurrent in the ice, trending to the southeast. As the valley contracts this becomes less evident and the western bank, with striæ in the direction of southwest flow, shows it was receiving the impact of the general moving ice sheet. In such a narrow, constricted gorge the local sub-current might be expected to die out, the trench would become packed with nearly motionless ice, up to the average level of the plateau, which would support the ice-sheet moving transversely across it. It seems improbable, therefore, not only that the basin was cut by the ice, but even that the pre-glacial valley was to any great extent deepened by its scour. The general appearance of the gorge, and the lack of truncated spurs, seems also to indicate no great amount of glacial control of its topography. It probably existed pretty much as it is to-day before the advent of the continental ice-sheet.

The explanation of a morainal dam also seems improbable when one considers the depth of the lake, the fact that the deepest part is not near the outlet but near the middle, and the character of the river bed below the outlet. There is no direct evidence of such a dam, and, as Barlow* remarks of the river bed below the outlet: "Very little rock *in situ* can now be seen, although it is evident from the topography that the detritus was deposited in a pre-existing shallow narrows." Even were it admitted that the valley was dammed with glacial drift to a depth of 500 feet at this point, there would still be a rock barrier at the Mountain Rapids at the foot of the next stretch of still water, known as Seven League Lake, whose surface is about 50 feet lower than that of the main lake above, and which discharges down a rapids obstructed by rocky reefs and islets. Thus, even if a morainal dam exists of the great depth postulated, it can only be regarded as a secondary affair, forming a sort of facing on the downward slope toward the lake center of the bed-rock barrier beneath and giving at the most a height of some extra 50 feet to the lake.

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*Loc. cit. p. 171.

It is not intended, of course, to deny in this that morainal deposits may not lie on the floor of the old canyon. They probably do, and the real rock floor may lie considerably deeper than the present bottom of the lake. At old Fort Narrows (B, on map) the gorge in large part is filled with a glacial deposit nearly choking the pre-existing narrows at this point. This very probably represents material accumulated by the local southeastward sub-glacial current in the ice which would be checked at this point. Only, as Barlow remarks, it could not have been originally much greater than it is now since on the down-stream side it slopes off with great sharpness to the depths of the lake. If it once projected somewhat above the present lake surface it was rapidly cut away until a grade was established between the two parts of the lake, and since then no great change in it has occurred.

The first two hypotheses of lake origin having been considered and dismissed there remains the third, and it now seems fairly evident that the lake represents a pre-glacial canyon which, by down-warping in its middle part, has become flooded. The total amount of down warp may be roughly estimated to be as much as 500 feet in the center of a distance of 50 miles in a general north to northwest and south to southeast direction.

Lake Kipiwa.—If such down-warping has occurred, it can scarcely be supposed that the immediate region would not be affected by it and the other drainages and lakes should show evidences of it. While not enough is known of those geologic features of the area which would offer decisive evidence on this point, there are some facts which appear to favor it. Thus Lake Kipiwa is so near to Lake Temiskaming and parallels it for such a distance that it should also be affected. It has not been seen by the writer, but Barlow describes it as filling several valleys parallel in a general way to Lake Temiskaming. These, like Temiskaming, cut across the general direction of foliation of the gneissic rocks. The depth of the lake is not known. It has at present two outlets, the natural one by the Kipiwa River at the north end, and an artificial one produced by a dam at the outlet of the lake into the Kipiwa river and by the blasting away of the crest of a low rocky barrier by the lumbermen which causes the lake to discharge by Gordon's Creek into Temiskaming at the point marked "Outlet" on the map. Thus it would appear as if the canting of the lake to the north by the down warp had left the old outlet dry and caused it to seek a new one by the Kipiwa River. The latter, as it enters Temiskaming, is a swift, foaming torrent which plunges down over the rocks into the main lake at a point where the latter is nearly 400 feet deep, without entering through any distinct valley. As one sees it, it appears to have all the marks of topographic youth.

Lake Temagami.—This lake, some 40 miles to the west of Temiskaming, is also a many branched valley system which has been flooded and which discharges by two natural outlets, one at the north, the other at the south end. Neither of these has been seen by the writer, but from what he has been able to learn it is inferred that both are over rock rims. The greatest depth of the lake obtained by sounding near the central west shore is about 170 feet. The double outlet in connection with the warped character of the Temiskaming canyon is very suggestive, but since the direction of the axial line of the warped trough, as it would pass westward from Temiskaming, is not known, it may pass through Temagami Lake, or to the north, or south of it. In the first case the valley system would be flooded, and former water-work on shores near the central part would be drowned; if either of the latter two, the lake would have been canted north or south respectively and wave-work, such as beaches or sea-cliffs, would be elevated at the north or south ends. It should also not be forgotten that as the lake has many arms, some of them may have served as a former outlet and have been choked by a moraine dam which has caused the flooding and overflow elsewhere of the valley system. These are points which can only be settled by a careful study of its entire shore line, and it offers an attractive problem for investigation.

Drainage System.—In this connection attention is also directed to the remarkable drainage plan of the region (fig. 1). It is impossible to see it and avoid the conviction that there has been a distinct control in its production by rock structure. What is here evident on a small scale map is also striking on the large scale one of the mining district prepared by Miller.* This feature of the region has been previously commented upon. Bell,[*] in noting the course of Lake Temiskaming, suggests that it follows the course of a great dike which has been eroded; a suggestion which Barlow's geological map shows to be untenable. Hobbs,[†] in a short paper on fracture systems, briefly alludes to this drainage plan and gives a map of a part of the area showing its peculiar nature. He attributes it to joints. Miller[‡] gives a more extended discussion of the systems of lines, and states that it is impossible to tell whether they follow faults or folds.

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* 14th Ann. Rep. Bureau of Mines, Ontario, 1905.

A study of Barlow's geologic maps of the Nipissing and Temiskaming sheets shows that these depressional lines of drainage are independent of the distribution of the rocks. The Montreal River, which holds a straight course through graywacke, slate, quartzite, and diabase, is a striking example of this. In a few cases, however, as plotted on the map, they appear to lie over the contact of formations. A consideration of the strike, especially of the planes of foliation of the gneissic areas, shows that they sometimes follow it, but just as often, and especially in the larger depressions, cut directly across it.

Either the drainage plan is directly conditioned by the present rock structures, or it is one that has been inherited; that is to say, it is superimposed upon the present surface by overlying formations, which once existed but have now disappeared. It is true that a remnant of an overlying formation, generally attributed to the Niagara, is found at the north end of Lake Temiskaming, but to restore this over the whole region would not only involve great improbabilities but would in itself give no explanation, for we should still have to account for the conditions in such an overlying series which would initiate such a drainage. It is also difficult to see how simple folding could produce such a rectangular net-work. On the whole, as suggested by Hobbs and Miller, it seems most probable that a system of nearly right-angled jointing and faulting has initiated planes of structural weakness through the region, which the streams have taken advantage of, and which has therefore exercised a directive control over them. While, as Miller remarks, it is difficult to directly prove this, since such lines of weakness in rock structure, or of displacement, are now for the most part covered by lakes, streams, and swamps, yet some corroborative evidence may be gleaned from Barlow's report where the jointed character of the rocks along the Montreal River is mentioned, and in one place of the direction of these joints as determining the course of the river.[§] Many more such instances should be found when the region is more closely studied.

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[*] Bull. Geol. Soc. America, vol. v, p. 365, 1894.

[†] Trans. Wisc. Acad. Sci., vol. xv, p. 19, 1905.

[‡] Rep. of the Bureau of Mines, Ontario, vol. xvi, pt. ii, 1907, p. 36.

[§] Loc. cit., p. 224.

If it be admitted that the drainage system is the outward revelation of an inward one of rock-fracturing, weakness, and probably to some extent displacement, then the network appears like the result of Daubrée's experiment on the induction of jointing by torsional warping.* It would seem natural to refer the lakes in part to minor warps or displacements of preexistent channels along these lines of weakness, although in part they are probably due to morainal dams and to glacial scour.

Time of Warping.—If such warping with fracturing has taken place, the questions naturally arise as to when it occurred and if it is still continuing. The region has, as yet, not been studied in sufficient detail, with such questions in mind, to afford decisive answers. Some facts there are, however, which have a bearing on these points. Thus Miller† points out that the mineral veins follow closely the same systems as the water courses, and the deduction from this must follow that they are either contemporaneous or later than the formation of the fracture system. But the silver veins have been glaciated and consequently the fracture system is pre-glacial. Miller indeed refers it to post-middle Huronian time, this view being based on the hypothesis that the deposition of the ores was the result of the intrusions of diabase which are referred to this period. But inspection of the maps shows that the larger elements of the fracture systems, as indicated by the drainage lines, pass through these diabases as well as the older rocks. A careful study of the Niagara group, and especially of its contact with the older rocks, may throw much light on this question.

Whether the crustal movements here assumed continued after the glacial period and are still going on is a problem which demands further investigation. Miller‡ states that post-glacial faulting can be proved to have taken place. A noticeable feature of the region are the open torsion cracks and joints seen on glaciated rock-surfaces which have not been filled or eroded. They have been illustrated by Miller. While these are indications, more positive evidence would come, as has been previously suggested, from the canting of the lakes and exposures of uplifted beaches and marks of wave-work on shores. If such canting is pre-glacial these would be largely swept away, but if warping has continued into post-glacial times or been renewed, the evidence to prove it can undoubtedly be gathered.§

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* Géologie Expérimentale, p. 510, 1879.

† Loc. cit., p. 38. ‡ Loc. cit., p. 38.

§ Since this paper was presented, and at the time of putting it in form for publication, the program of papers to be read at the Boston meeting of the Geol. Soc. Amer. has been received. In this is listed a paper by Dr. Robert Bell entitled the "Diversion of the Montreal River," and in the attending

Summary.—The ideas expressed in this paper may be now briefly summarized. That in this region there was first initiated by torsional warping in pre-glacial times a system of jointing, fracturing, and structural lines of rock weakness, and possibly foliation, which has controlled the drainages. That later, or continuing, warping has caused the beginning of a broad synclinal fold with the production of the larger lakes and other modifications of drainage; that this has taken place or continued into post-glacial times and may still be in progress, and that this is a minor feature of the uprise of the great Ontarian shield. It is not intended to assert that this idea or all parts of it are necessarily correct, or proven; only that the facts, so far as published and known, appear to point in this direction. For the object of this paper is not so much to state an hypothesis as to direct attention and to start an inquiry.

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short synopsis the view is advanced that the Montreal River in post-glacial times has been diverted from a former northward direction and made to flow southward by an uprise of the land which gives a southward tilt to its present course. This is in the region north of that covered by the map accompanying this article. While the writer has not heard this paper, this view, as thus stated, appears to favor the general idea expressed in this article and the southward flow of the river down the northern flank of the warp to be a local feature of the more general problem here presented.

ART. IV.—*The Jurassic Age of the "Jurassic Flora of Oregon"*;* by F. H. KNOWLTON.

INTRODUCTION.

THE stratigraphic and paleontologic relations of the earlier Mesozoic rocks of the Pacific Coast region, more particularly the Knoxville and related formations, have been the subject of prolonged investigation, and, it may be added, not a little difference of opinion as regards their interpretation. Mr. J. S. Diller, of the U. S. Geological Survey, is especially notable among those who have made this area the subject of study, and to his interest and energy we are principally indebted for the bringing to light of the numerous and often exhaustive collections of fossil plants. To Prof. Lester F. Ward and Prof. Wm. M. Fontaine we are also under obligation for the adequate study, illustration, and publication of these floras, without which they would, doubtless, have long remained unavailable for stratigraphic uses. Although the story told by the floras is seemingly plain and unequivocal, the conclusions of the paleobotanists have not always been given full consideration, and it is the object of the present paper to present this paleobotanical evidence in compact form, together with such stratigraphic and other paleontologic data as may be necessary to make the position clear.†

In November 1908, Mr. Diller published a paper under the title, "Strata containing the Jurassic Flora of Oregon,"‡ the thesis of which he sets forth as follows: "Two fossil floras have been reported from the Mesozoic rocks of California and Oregon, the one Cretaceous and the other Jurassic. With the former the fauna is Cretaceous, but with the latter the fauna has been regarded as a matter of doubt. It is the purpose of this paper to remove the doubt by showing that in parts of Oregon and California the Jurassic flora, ... is in the 'Myrtle' and Knoxville beds, while elsewhere it extends down to the horizon of the Mariposa, and the general conclusion is reached that for the Pacific Coast the line between the Cretaceous and the Jurassic is the great unconformity at the base of the Knoxville."

The major portion of Mr. Diller's paper is devoted to proof that the Jurassic flora occurs in the Knoxville formation—a point conceded by the present writer. It is to the placing of the Jurasso-Cretaceous line at the base of the Knoxville that exception is taken.

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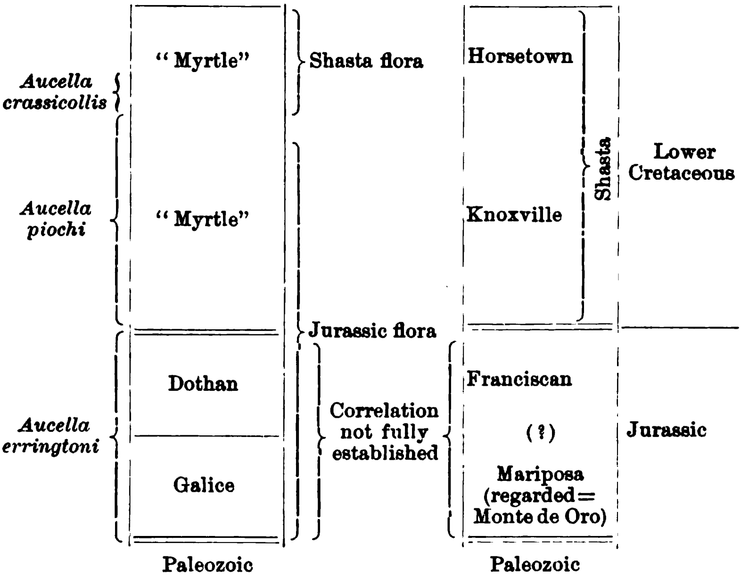
* Published with the permission of the Director of the U. S. Geological Survey.

† The writer labors under the disadvantage of not having seen in the field the several formations here involved, and consequently the discussion is confined mainly to the paleobotanical evidence. The geological data are largely from Diller.

‡ Geol. Soc. Am., Bull., vol. xix, pp. 367–402, 1908.

Mr. Diller's interpretation of the relations of the several formations concerned in this paper, together with his conclusion regarding the ranges of the floras and the supposedly characteristic invertebrates, is shown in the following diagram, which is taken from his paper (p. 369):



Thesis of this Paper.

At variance with the conclusions above set forth, it will be shown in the present paper that the so-called "Jurassic flora of Oregon" is everywhere of true Jurassic age, that it is practically never* found in association with the acknowledged Cretaceous flora, and finally, that the line between the Jurassic and the Cretaceous of the region is to be drawn through the upper part of the Knoxville and not at its base.

Localities of the Several Plant Beds

The localities which have afforded the floras are as follows: The "Jurassic flora of Oregon" occurs at three points in Oregon—(1) Thompson Creek and the vicinity of Buck Peak; (2) near Nichols Station on the Southern Pacific railroad, both in Douglas County; (3) along the forks of Elk River in Curry County. In California there are also three areas: (1) Big Bar and (2) Rattlesnake Creek in the Klamath Mountains, Trinity County, and (3) near Oroville, Butte County, the latter at the western base of the Sierra Nevada.

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* The only possible exceptions are a scrap very doubtfully identified from the area near Riddles, Oregon, and a conifer of no stratigraphic value from California.

The Lower Cretaceous flora[†] is found along Iron Mountain Creek in the vicinity of Riddles, Douglas County, Oregon; at Redding Creek, Tehama County, California, and very extensively along the western side of the Sacramento Valley in Shasta and Tehama counties, California. The Jurassic and Lower Cretaceous floras, although occurring in the same areas, are perfectly distinct and have never been found commingled.

STRATIGRAPHIC RELATIONS OF THE BEDS CONTAINING THE "JURASSIC FLORA OF OREGON."

1. Thompson Creek, Douglas County, Oregon.

The beds exposed along Thompson Creek are 1000 feet or more in thickness and dip westward at an angle of about 38°. The lower three-fourths of the section is composed of conglomerates, with small local beds of sandstones and shale, while the upper third is made up of sandstone and shale. Although plant fragments are found at various points in the conglomeratic portion, the principal plant beds are in shaly sandstone about 180 feet below the top of the exposed Mesozoic section. This is one of the richest of the Jurassic plant localities, having furnished 66 species (see pp. 43–45).

As regards the invertebrates found at this locality Mr. Diller says:[*] "Shells are of exceptional occurrence in the leaf beds. Though carefully sought for, they have rarely been found. A doubtful fragment found with the plant fossils in Thompson Creek was referred to Doctor Stanton, who reported that "the fragment seems to be part of a shell and is probably an Aucella, although there is not enough of it for positive identification."

2. Buck Peak, Douglas County, Oregon.

On the northeastern side of Buck Peak, 1,200 feet below the summit, there is an important plant locality which is really embraced in the Thompson Creek area already considered.

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[*] The flora, called in this paper the "Lower Cretaceous Flora," has heretofore been called the "Shasta flora," but since it does not occur throughout the whole of the Shasta series it has seemed best to abandon its use. It may be desirable at some time in the future to give separate names to the portions of the Shasta series containing the Cretaceous and Jurassic floras respectively.

[†] Geol. Soc. Am., Bull., vol. xix, p. 373, 1908.

At the summit there are found the invertebrates *Aucella Piochi* and *A. crassicollis*, but between the summit and the plant bed, 1,200 feet below, only faint indications of plants have been noted, though according to Mr. Diller "The plant beds at the so-called Todd locality conformably underlie by a few feet only a conglomerate containing indefinite vegetable fragments as well as good specimens of *Aucella Piochii*." From the presence of shells and plants and the lithologic similarity of the intervening beds to those of the Myrtle, the whole is referred to this formation.

The only Jurassic plant in any way determinable that was found in the area and strata usually containing a Lower Cretaceous flora, occurred about 3 miles northeast of Riddles. This was a minute fragment, which was very questionably identified as *Tæniopteris oregonensis*, and was found in association with *Aucella Piochii*. If this identification had been positive, or even reasonably certain, it would be the only known instance of the two floras overlapping, but it is altogether too fragmentary to be taken as conclusively affording such evidence.

3. Nichols Station, Douglas County, Oregon.

This is a small area, mainly on Cow Creek, about half a mile north of Nichols Station, and is entirely surrounded by rocks of Eocene age. The beds, only about 200 feet in thickness, are composed of "fine, dark, shaly sandstone or sandy shale." Their relations to the underlying beds cannot be observed, and their reference to the Myrtle was based largely on a single specimen of *Aucella Piochii*, which was in a loose piece of matrix, not certainly found in the plant beds. As a locality for the Jurassic flora, however, it is of the greatest importance, no less than 45 forms having been found here. [See table on pp. 43–45.]

4. Elk River, Curry County, Oregon.

This area, which lies about 40 miles directly southwest of the areas in Douglas County, is of limited extent, ranging along Elk River from near the mouth of Blackberry Creek to the forks of the river and up the North fork for a distance of about a mile and a half; on the South fork the plant beds extend for only 200 yards. The section is about 1000 feet in thickness and is made up of sandy shale, much veined with calcite, "frequent layers of calcareous material, beds of sandstone, and fine conglomerate."

According to Mr. Diller,* "These plant beds are underlain on the South fork by a mass of conglomerate containing in its lower part many large pebbles of the greenstone like that on which the conglomerate rests at the base of the 'Myrtle.' No plants were found in the basal conglomerate, though it contained many examples of *Aucella crassicollis*." On this evidence the entire section was regarded as referable to the Myrtle formation.

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* Op. cit., p. 376.

Since the above quotation was published, in fact during the past summer (1909), Mr. Diller has visited and re-examined the Elk River region of the Port Orford quadrangle, and made the following important observations which he has kindly permitted me to make use of. The plant beds—that is, the beds containing the "Jurassic flora of Oregon"—he now finds to be over 1,200 feet in thickness; they rest comformably on a conglomerate which he regards as the basal member of the Myrtle (Knoxville). This conglomerate contains "multitudes" of *Aucella crassicollis* in the upper portion, while *Aucella Piochii* occurs, though somewhat rare, near the bottom. This conglomerate rests unconformably on a mass of greenstone, which has supplied the pebbles in its basal portion. This greenstone mass, in turn, has cut the underlying crushed and quartz-veined slates and sandstones of the Dothan? which latter contains locally, as identified by Doctor Stanton, *Aucella Piochii* and *Aucella Erringtoni* in association. This distribution of the several species of Aucella in this section is very significant, and will be referred to on a later page.

The Elk River area has furnished two considerable collections of fossil plants which together aggregate 20 species [see table on pp. 43–45]. As this entire flora, with the exception of the unnamed specie of Hausmannia, is identical with that found in Douglas County, it may be considered as settled that the two areas are of the same age.

This is also the first of the areas thus far considered in which an identifiable invertebrate fauna is found in direct association with the plants. The following list of names is given by Doctor Stanton:*

Spondylus? sp.
Aucella crassicollis Keyserling
Inoceramus ovatus Stanton
Turbo morganensis Stanton
Olcostephanus mutabilis Stanton
Perisphinctes? sp.
Hoplites Hyatti Stanton
Belemnites tehamæensis Stanton
Belemnites impressus Gabb
Pinna.

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* In Diller, Geol. Soc. Am., Bull., vol. xix, p. 378, 1908.

Doctor Stanton makes the following comment on this fauna: "The collection consists of a number of small lots containing very few specimens, the most abundant and persistent being *Aucella crassicollis* Keyserling, which past experience shows to be characteristic of the upper part of the Knoxville formation and is believed to be confined to the Lower Cretaceous. In several of the lots there are a few ammonites and other fossils that are also Knoxville forms."

The significance of this association of flora and fauna will be considered later.

5. *Big Bar, Trinity County, California.*

This area, which covers less than two square miles, is on the Trinity River, about twenty miles west of Weaverville, California, and is not less than 150 miles from the areas already considered in Oregon. The entire section of Jurassic rocks in this vicinity does not exceed 200 feet in thickness, and lies on the sharply upturned edges of older, probably Paleozoic strata, and is itself inclined from 20 to 45°. It is composed of soft "gray shales and sandstones, with a small proportion of fine conglomerate," and apparently belongs to the lower part of the Knoxville.

Fossil plants are abundant in this locality, and are scattered irregularly throughout the section, though most numerously in the lower portion. They embrace 20 well-marked species [see table on pp. 43–45] and as stated in the original report, they "prove beyond question that the beds containing them are similar in age to the Jurassic of Oregon, since all but three of the forms (*Onycohiopsis* [fruit], *Hausmannia*, and *Pagiophyllum falcatum*) are common to the two areas."

In the same bed with the plants a few shells have been found. Only one of these has been positively determined as *Aucella crassicollis*, the others being unidentified forms of *Pecten*, *Mytilus*, *Cyprina*, and *Unio*, the latter proving that there were alternations of fresh-water and salt-water conditions. These fossils, says Doctor Stanton, "are certainly upper Knoxville and hence Lower Cretaceous, as shown by the presence of typical specimens of *Aucella crassicollis*."

6. *Rattlesnake Creek, Trinity County, California.*

Twenty-five miles south of Big Bar there is another small area of Jurassic plant-bearing beds lying in the drainage of Rattlesnake Creek, 7½ miles southwest of Peanut, Trinity County, California. As at Big Bar, the plant beds reston the upturned edges of older rocks.

Only three species of plants have been found at this locality: *Cyclopitys oregonensis* Font., *Tæniopteris vittata* Brongn., and *Sequoia Reichenbachi* (Gein.) Heer. The latter species is a form of such wide vertical range that it is of little value in fixing the age of beds in which it may occur, hence its inferential use to prove the beds on Rattlesnake Creek to be of extreme upper Knoxville or lower Horsetown age, where this species has also been found, is not warranted.

Many shells are stated to be present in the same strata with the plants, concerning which Doctor Stanton reports as follows: "Among the fossil plants are two small shells which appear to be young specimens of *Unio*, though they may belong to some marine genus instead."

7. *Oroville, Butte County, California.*

At this locality Jurassic rocks form an area about 2 miles in length and 2/5 of a mile in width, on the southern slope of Monte de Oro, about 3 miles northeast of Oroville, Butte County, California. These rocks, to which the local name of the Monte de Oro formation has been given, are composed of "slates, sandstones, and conglomerates in small layers, irregularly interbedded"; they are much disturbed and the true thickness cannot be made out, though thought to be somewhere between 450 and 900 feet.

This area has afforded a rich flora, and was the first to be described of any considered in this paper; it contains 27 species [see table on pp. 43–45]. They are typically Jurassic, and as nearly half were subsequently found to be common to the Douglas County region they are of much importance in settling the Jurassic age of the plant beds in the latter area. Unfortunately the invertebrate collections are not large from the plant beds at Oroville, and comprise new or undeterminable species of the genera *Ostrea*, *Pecten*, *Aucella ?*, *Modiola*, *Trigonia*, *Cardium ?* and *Belemnites*. Regarding the age as indicated by the Aucella ? Doctor Stanton says: "If it is really an Aucella the age is either Mariposa or Knoxville, more probably the former. The general character of the other forms is suggestive of the older Jurassic faunas of the Taylorsville region, but it must be admitted that there is no definite evidence of this."

STRATIGRAPHIC RELATIONS OF THE BEDS CONTAINING THE LOWER CRETACEOUS FLORA OF OREGON AND CALIFORNIA.

1. *Near Riddles, Douglas County, Oregon.*

In the vicinity of Riddles, Oregon, and including a small area on Iron Mountain Creek, there is a mass of rocks that has been pretty definitely connected with the upper portion of the Myrtle formation, since it is directly on the strike with that of the type locality for the Myrtle on Myrtle Creek in the Roseburg quadrangle. These beds contain a small but very important flora of 8 species, as follows:

Sagenopteris Mantelli? Schenk
Sagenopteris oregonensis Font.
Sagenopteris nervosa Font.
Angiopteridium strictinerve latifolium Font.
Dioonites Buchianus abietinus Ward.
Nageiopsis latifolia Font.
Populus? Ricei Font.
Sapindopsis oregonensis Font.

This flora is identified without hesitation as being of Lower Cretaceous age, or Neocomian. The presence of the species of dicotyledons shows conclusively that it is younger than the "Jurassic flora of Oregon," a fact also proved by the stratigraphic relations and invertebrate fauna. The latter, although stated to be abundant, is not listed by Mr. Diller, though held to be characteristic and proving the correlation between these beds and those containing a similar fauna on the western side of the Sacramento Valley.

The stratigraphic relations between the beds near Riddles which contain the Lower Cretaceous flora, and those to the northwest containing the Jurassic flora, is well set forth by Mr. Diller* in the following statement: "A line of deformation runs northeast and southwest through the region of Nickel Mountain and Dodson Butte. It follows a prominent ridge and appears to mark approximately the limit between the two floras of 'Myrtle formation.' Southeast of it lies the Riddles region and Iron Mountain Creek, where the "Myrtle formation" contains the 'Shasta flora,' while to the northwest of it lie the larger irregular areas of the 'Myrtle,' containing locally on Thompson Creek and Elk River the 'Jurassic flora of Oregon.' At one point the line of deformation is overlapped by the Jurassic flora, where it reaches Cow Creek at Nichols Station. In general, on account of the overlapping 'Myrtle formation,' it may be claimed that the 'Myrtle' containing the Jurassic flora lying northwest of that containing the Shasta flora must be older. So it seems also from the entire absence of any Horsetown fauna on the northwest side of the axis in the same series near the Jurassic flora."

From this exposition it appears very clear that the Myrtle formation may be divisible, at least paleontologically, into two parts, the upper of which is characterized by the presence of a Lower Cretaceous flora and fauna, while the lower is equally marked by the presence of a Jurassic flora. The two floras have never been found commingled, but the fauna is occasionally, as at Elk River, also found interbedded with, as well as below, the Jurassic flora, showing that it has a greater vertical range than has usually been accorded to it.

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* Op. cit., p. 397.

2. Western Side of the Sacramento Valley in Shasta and Tehama Counties, California.

This is much the largest and most important of the areas which have afforded the Lower Cretaceous flora. It is found at many localities on the North fork of Cottonwood Creek near the town of Ono, Shasta County, and along the Cold fork and South fork of Cottonwood Creek, as well as near the Post Office of Lowrey and as far south as Paskenta, all in Tehama County. The field relations of this region have been so fully set forth by Professor Ward* and Mr. Diller that it is unnecessary again to go over the matter.

This area is also notable as that which has supplied the major portion of the Knoxville fauna, and since small portions of this fauna were found in association with the Jurassic flora at Elk River, Big Bar, etc., it was assumed by some that the flora of the western side of the Sacramento Valley would present the same associations–that is, prove to be a Jurassic flora–but it very distinctly is not. By combining the floras collected by Professor Ward and studied by Professor Fontaine, with those collected by James Storrs for Mr. Diller and reported on by the writer, we have the following aggregate list of 59 forms, only a single species of which is common to the Jurassic flora. It is distinctly a Lower Cretaceous (Neocomian) flora and finds its closest affinity with the Kootenai of the interior region, the Trinity of Texas, and the lower Potomac of the Atlantic Coastal Plain. A further analysis and comparison will be made in later pages.

List of Lower Cretaceous Flora of the Western Side of the Sacramento Valley.

Dicksonia pachyphylla Font.
Thyrsopteris rarinervis Font.
Cladophlebis parva Font.
" *Browniana* (Dunk.) Sew.
" *falcata* Font.
" *heterophylla* Font.
" *Ungeri* (Dunk.) Ward.
" *alata?* Font.
Matonidium Althausii (Dunk.) Ward.
Gleichenia Nordenskiöldi Heer.
" ? *Gilbert-Thompsoni* Font.

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* U. S. Geol. Surv. Mon. 48, p. 211 et seq., 1905.

Sagenopteris Mantelli (Dunk.) Sew.
“ *oregonensis* (Font.) Font.
“ *elliptica* Font.
“ *nervosa* Font.
“ *?* sp. Font.
Tæniopteris sp. Kn.
Hausmannia? californica Font.
Angiopteridium canmorense Dawson ?
“ *strictinerve* Font.
“ *strictinerve latifolium* Font.
Oleandra graminæfolia Kn.
Ctenopteris integrifolia Kn.
Ctenis sp. Kn.
Equisetum texense Font.
Dioonites Dunkerianus (Göpp.) Miq.
“ *Buchianus* (Ett.) Born.
“ “ *abietinus* Ward.
“ “ *rarinervis* Font. ?
Nilsonia Stantoni Ward.
“ *Shaumbergensis* (Dunk.) Nathorst.
“ *californica* Font.
“ *sambucensis* Ward.
“ sp. Kn.
Pterophyllum lowryanum Ward.
Ctenophyllum ? latifolium Font.?
Zamites arcticus Göpp.
“ *tenuinervis* Font.
Cycadeospermum alifornicum Font.
“ sp. Kn.
Cephalotaxopsis ramosa Font.?
“ *rhytidodes* Ward.
Nageiopsis longifolia Font.
“ *latifolia* Font.
Abietites ellipticus Font.
“ *macrocarpus* Font.
“ sp.
Pinus shastensis Font.
Sequoia Reichenbachi (Gein.) Heer.
“ *ambigua* Heer.
Sphenolepidium Sternbergianum (Dunk.) Heer.
Saliciphyllum pachyphyllum Font.
“ *californicum* Font.
Populus ? Ricei Font.
Proteæphyllum californicum Font.
Menispermites californicus Font.
Sapindopsis oregonensis Font.
Acaciæphyllum ellipticum Font.
“ *pachyphyllum* Font.

3. Redding Creek, Trinity County, California.

The final area of beds holding a Lower Cretaceous flora to be considered is the small one on Redding Creek, near Douglas City, Trinity County, California. It is said that the beds at this locality lap over the crest of the Coast Range from the Sacramento Valley, and are of the same age as the beds in the latter area. The flora is a small one, comprising only the following species:

Sagenopteris oregonensis Font.
Sagenopteris elliptica ? Font.
Gleichenia ? Gilbert-Thompsoni Font.
Cladophlebis heterophylla Font.
Sequoia Reichenbachi (Gein.) Heer.

These specimens, with the exception of *Cladophlebis heterophylla*, which is known from the Kootenai and lower Potomac, are all reported by Fontaine and the writer from the Lower Cretaceous flora of the localities along the western side of the Sacramento Valley, in direct connection with these beds, as stated above.

The fauna associated with the plants embraces *Pecten operculiformis*, *Trigonia leana*, *Cardium ?*, *Corbula*, and *Pleuromya papyracea*, and is regarded by Doctor Stanton as belonging to the lower Horsetown.

TABLE SHOWING LOCAL DISTRIBUTION OF THE JURASSIC FLORA.

As a preliminary to the proper consideration of the Jurassic flora in all its aspects, we may first present a table which gives a complete list of forms known, together with their distribution among the several localities in Oregon and California. The number, or numbers, opposite each species, refer to the localities as follows:

1 = Thompson Creek, Oregon.
2 = Buck Peak, Oregon.
3 = Nichols Station, Oregon.
4 = Elk River, Oregon.
5 = Big Bar, California.
6 = Rattlesnake Creek, California.
7 = Oroville, California.

Marchantites erectus (Bean) Sew., 1.
Dicksonia oregonensis Font., 1, 2, 4, 5.
Coniopteris hymenophylloides (Brongn.) Sew., 3, 7.
Thyrsopteris Murrayana (Brongn.) Heer, 1, 3, 4.
Polypodium oregonense Font., 1, 2, 3, 4.
Cladophlebis vaccensis Ward, 1, 2, 3, 4, 5, 7.
" *haiburnensis* (L. & H.) Br. ? 1.
" *acutiloba* (Heer) Font., 1, 3.

Cladophlebis denticulata Font., 5?
“ *pecopteroides* Font., 2, 4?
“ *sphenopteroides* Font., 5.
“ *spectabilis* (Heer) Font., 7.
“ *argutula* (Heer) Font., 7.
“ *densifolia* Font., 7.
“ *indica* (O. & M.) Font., 7.
“ sp., Kn., 5.
Scleropteris oregonensis Font., 3, 5?
Ruffordia Göpperti (Dunk.) Sew., 1.
Adiantites Nympharum Heer? 1, 3.
“ *orovillensis* Font., 7.
Tæniopteris orovillensis Font., 1, 2, 3, 5, 7.
“ *major* L.? & H., 1, 2, 3.
“ *vittata* Brongn., 1, 2, 3, 5, 6.
“ *? oregonensis* Font., 1, 4.
“ sp., 5.
Macrotæniopteris californica Font., 1, 7.
“ *nervosa* Font., 7.
Angiopteridium californicum Font., 7.
Sagenopteris Göppertiana Zigno, 1, 2, 4, 7.
“ *paucifolia* (Phil.) Ward, 1, 2, 3, 4, 5.
“ *grandifolia* Font., 1, 5.
Danæopsis Storrsii Font., 1.
Didymosorus? bindrabundensis acutifolius Font., 7.
Hausmannia sp., 4, 5.
Onychiopsis psilotoides (Stokes & Webb) Ward? 5.
Equisetum? sp., Font., 1, 3.
Ptilozamites Leckenbyi (Bean) Nath., 3.
Nilsonia orientalis Heer, 1, 2.
“ “ *minor* Font., 1, 2, 3, 4, 5.
“ *parvula* (Heer) Font., 1, 2, 3, 4.
“ *nipponensis* Yokoyama, 1.
“ *compta* (Phil.) Göpp., 1, 3.
“ *pterophylloides* Nath., 1, 3.
“ sp., Kn., 4.
Pterophyllum Nathorsti Schenk, 1, 2, 3.
“ *contiguum* Schenk, 1, 2, 3.
“ *æquale* (Brongn.) Nath., 1, 2, 3.
“ *rajmahalense* Morris, 1, 2, 3.
“ *minus* Brongn., 1.
Ctenis grandifolia Font., 1, 2, 3, 7.
“ *auriculata* Font., 1?, 7.
“ *orovillensis* Font., 1, 7.
“ *sulcicaulis* (Phil.) Ward, 1, 2, 3, 4?
Ctenophyllum angustifolium Font., 1, 4, 7.
“ *pachynerve* Font., 3.
“ *Wardii* Font., 1, 2, 3, 7.
“ *?* n. sp.? Font., 4.
“ *densifolium* Font., 7.
“ *grandifolium Storrsii* Font., 7.

Podozamites pulchellus Heer, 1, 2, 3.
" *pachyphyllus* Font., 2, 3.
" *lanceolatus* L. & H., 1, 2, 3, 7.
" " *latifolius* (Brongn.) Heer, 1, 4, 7.
" " *minor* (Sch.) Heer, 1, 4, 5.
" sp., Kn., 4.
" ? *pachynervis* Font., 1.
Otozamites oregonensis Font., 4.
Encephalartopsis? oregonensis Font., 2.
Cycadeospermum oregonense Font., 1.
" *ovatum* Font., 1.
Williamsonia oregonensis Font., 1.
" ? sp., Font., 1.
" ? sp., Font., 3.
Ginkgo digitata (Brongn.) Heer, 1, 3.
" *Huttoni* (Sternb.) Heer, 1, 3.
" " *magnifolia* Font., 1, 2, 3.
" *lepida* Heer, 1, 2, 3.
" *siberica* Heer, 1, 3.
" sp., Font., 1, 3.
Baiera multifida Font., 7.
Phœnicopsis? sp., Font., 1.
Taxites zamioides (Leck.) Sew., 1, 2, 3, 4, 5.
Brachyphyllum mamillare Brongn., 1.
Pagiophyllum Williamsonis (Brongn.) Font., 7.
" *falcatum* Font., 5 ?
Araucarites sp., Font., 1.
Pinus Nordenskiöldi Heer, 1, 3, 7.
Sequoia Reichenbachi (Gein.) Heer, 6.
Cyclopitys oregonensis Font., 1, 6.
Sphenolepidium oregonense Font., 1, 2, 3, 5.
Samaropsis? oregonensis Font., 1.
Leptostrobus? sp., Font., 7.
Yuccites hettangensis Sap., 1, 5 ?
Undetermined leaf No. 1, 1.
" " " 2, 1.
Carpolithus Storrsii Font., 7,
" *olallensis* Ward, 1.
" *Bucklandii* Will., 1.
" *oregonensis* Font., 1, 2.
" *elongatus* Font., 1.
" *douglasensis* Font., 3.

Discussion of the Distribution and Affinity of the Jurassic Flora.

Aside from furnishing a complete list of the forms thus far known from the Jurassic of Oregon and California, the above table brings out graphically a number of interesting points, perhaps the most important of which is the close interrelation of the floras of the several areas. Thus, of the 27 species composing the Oroville flora, 12 species occur also in the Douglas County areas. Of the 66 forms found on Thompson Creek, 32 are common to the localities near Nichols Station, and of the 20 forms occurring at Elk River, in Curry County, all but one are common to Douglas County. The close relation between the Oregon areas and that at Big Bar, California, is shown by the fact that all but 3 of its 19 forms are common to the former, and of the 3 species reported from Rattlesnake Creek, 2 are common to the Oregon localities and one to Big Bar. This proves beyond all reasonable doubt that the plant beds of the several localities are identical in age. Whatever is decided regarding any one of them must apply with equal force to all.

We may now proceed to an analysis of the flora to ascertain its bearing on the age of the strata. Of the 100 forms composing the flora 15 are not specifically named and 47 are found in outside areas, mainly beyond the limits of North America, thus leaving 38 species, or considerably less than fifty per cent., as endemic. Of these forms that are peculiar, Professor Fontaine* has well said that "none are incompatible with the conclusion that the age of the strata is Jurassic. On the contrary, so far as they throw any light on the question of age, they indicate that it is Jurassic."†

The value of species new to science and those whose determination is questioned, in attempting to fix the age of the beds containing them lies in their affinities, or close relationship, with species whose position is known. It may be worth while in the present connection to review a number of the peculiar species of this flora to ascertain their relationships. *Cladophlebis vaccensis* is very close to, and indeed was at first identified with, *Asplenium whitbiense tenue* Heer, from the Jurassic of Siberia. *Cladophlebis pecopteroides* is thought by Professor Fontaine to be the Oregon representative of *Pecopteris obtusifolia*, a species of the Yorkshire beds. *Scleropteris oregonensis* is close to *S. Pomelii* Zigno of the Italian Oölite. *Tæniopteris? oregonensis* may be a small, narrow leaf of *T. vittata*, though it has some resemblance to *Cycadites sibericus* Heer, of the Jurassic of Siberia, which is a Tæniopteris rather than a

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* U. S. Geol. Surv., Mon. 48, p. 141.

† Mr. Diller has given a portion of this quotation ["so far as they throw any light on the question of age, they indicate that it is Jurassic"] as a full expression of Professor Fontaine's opinion regarding the bearing of the Oregon plants on the question of age. As shown above, this quotation applies only to the new and not specifically named species, while Fontaine's opinions regarding the significance of the positively determined species occur on the two or three succeeding pages of his paper [U. S. Geol. Surv., Mon. 48, pp. 141–145].

Cycadites. *Danæopsis Storrsii* shows affinity with *D. marantacea* Heer, and *D. Rumpfii* Schimper, two Triassic species, though it is smaller. *Ctenophyllum angustifolium*, as Fontaine points out, is "plainly one of the narrow-leaved Ctenophylla of the type of *Ctenophyllum Braunianum* (Göpp.) Schimper." *Podozamites pachyphyllum* resembles a number of species, but is especially like *Pterophyllum? cteniforme* Nathorst, from the Rhaetic of Sweden. *Williamsonia oregonensis* very much resembles *W. gigas* (Will.) Carruthers, a well-known species of the Jurassic of France and elsewhere. *Tæniopteris orovillensis*, the most common fossil plant at Oroville, is very near the plant figured and described by Saporta as *T. tenuinervis* Braunn from the Infralias of France. *Macrotæniopteris californica*, which is also a common form at Oroville, is near *T. lata* Oldh. & Morr., of the Rajmahal flora of India. *Angiopteridium californicum* is quite similar to *A. McClellandi* (Oldh. & Morr.) Schimper, from the same locality and horizon as the last.

This comparison could be much further elaborated, but it is perhaps unnecessary.

A Comparison of the Jurassic Floras of California and Oregon Here Considered with Known Jurassic Floras of Other Parts of the World.

The Jurassic flora is one of the most widely known and uniformly distributed of any known fossil flora. Reaching its northernmost limit on King Karl's Land, 82° N., and its southernmost extension on Louis Philippe Land, 63° S., it is found entirely round the world in almost every continent and country—North America, Europe, Asia, Australia. Throughout this vast area it is to all intents and purposes practically the same flora. For example, many of the forms discovered on Louis Philippe Land are identical, or closely related, to those of the Oölite of Yorkshire, England, while many forms, identical or closely related, are common between the areas in England, Sweden, France, Italy, Germany, Siberia, China, Japan, India, or North America.

The types of the Jurassic flora are for the most part well marked, and even when only fairly well preserved are capable of very certain identification. When to this is added the fact that in most areas where this flora has been found its position is confirmed by contributary stratigraphic and paleontologic data, the fixation of a similar flora found in a new area is made easy and certain.

It is proposed to compare the flora here under consideration with that of several of the more important of the known Jurassic floras of the world, beginning with that of Eastern

Siberia. At first thought it may seem a far call from California and Oregon to Siberia, but when it is pointed out that there are a number of connecting points at which the Jurassic has been found in western British Columbia, southern and western Alaska, and thence out on the Alaskan peninsula, it is seen that we have here indication of a probable land connection between the continents in Jurassic time.

In 1876 Heer[*] published his first paper on this flora which included material from Kajamündung and Ust-Bali, Siberia, and the upper Amur River, and Bureja in the Amur. This was supplemented[†] in 1878 and 1880 by the study of further material from the original localities as well as from the Lena delta, etc. The number of species finally aggregated about 100, many of which have since been identified in widely different parts of the world, the greatest number (16 species) being common to the beds of Yorkshire, England. The age of the Siberian deposits was fixed by Heer as that of the middle Brown Jura (Dogger), which is about the equivalent of the lower Oölite of Yorkshire.

Following is the list of species common to California and Oregon and eastern Siberia:

Cladophlebis argutula
Cladophlebis acutiloba
Cladophlebis spectabilis
Thyrsopteris Murrayana
Thyrsopteris Maakiana
Nilsonia orientalis
Nilsonia parvula
Pterophyllum rajmahalense
Podozamites pulchellus
Podozamites lanceolatus
Podozamites lanceolatus minor
Podozamites lanceolatus latifolius
Ginkgo digitata
Ginkgo Huttoni
Ginkgo lepida
Ginkgo siberica
Seeds of *Ginkgo*
Pinus Nordenskiöldi
Brachyphyllum mamillare.

As Professor Fontaine has pointed out, the strata of Oregon and California rival those of eastern Siberia in the development of Ginkgos, and as he says, it is a noteworthy fact that nearly all of the more important forms described by Heer from those beds have similar forms in the Oregon strata. Certain of the forms, notably that known as *Ginkgo digitata*, have a distribution into somewhat later beds, but in these later horizons, such for example as the Kootenai formation, they are smaller and not present in such numbers. In fact the Ginkgos in the Lower Oölite time were immensely developed in the Amur region of Siberia and in the northwestern portion of the

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[*] Beiträge z. Jura-Flora Ostsibiriens u. d. Amurlandes. Mém. Acad. Imp. d. Sci. St. Petersb. (Fl. Foss. Arct., vol. iv, Abt. 2), vol. xxii, pp. 1–122, pls. i–xxxi, 1876.

[†] Op. cit., vol. xxiv, 1878 (Fl. Foss. Arct., vol. v, Abt.. 1), pp. 1–26. pls. i–vii. Op. cit., vol. xxii, 1880 (Fl. Foss. Arct., vol. vi, Abt. 1), pp. 1–34, pls. i–ix.

United States, a profusion of identical forms such as to suggest very forcibly the existence of a former land connection.

At the present point it will be of interest to consider the occurrence of Jurassic plants at various localities in Alaska, the first and in many respects most important being the areas along the west shore of Cook Inlet. In this area Stanton and Martin* have established the Enochkin formation, the upper part of which they regard as the equivalent of the Callovian of European standards. Following German usage, this is considered by these authors as belonging to the upper part of the Middle Jurassic, though according to the prevailing custom of English geologists it belongs to the upper part of the Lower Oölite. The upper two-thirds of the Enochkin formation, which has a total thickness of from 1,500 to 2,500 feet, is especially characterized by the presence of numerous species of Cadoceras, several other genera of ammonites, belemnites, etc. Associated with these shells, often being on the same pieces of matrix, were the following plants:

Cladophlebis denticulata
Ctenis grandifolia
Hausmannia sp.
Dictyophyllum cf. *D. obtusilobum.*

The lower third of the Enochkin formation contains a fauna very different from that of the upper portion. It is characterized by species of Stephæroceras, Sphæroceras, Phylloceras, Lytoceras, etc., the genus Cadoceras being absent, and the most common forms being the several species of Inoceramus described by Eichwald from this region. It is interesting to note that this fauna was originally referred largely, if not wholly, to the Neocomian by Eichwald, and also that several of its species were found to be the same as those from Queen Charlotte Islands, once referred by Whiteaves to the Cretaceous. Associated with the ammonites were the following plants:

Sagenopteris Göppertiana
Pterophyllum rajmahalense
Macrotæniopteris californica.

It is of importance to note that every one of the five named and positively identified species from the Enochkin formation occurs in the Oroville (Monte de Oro) flora. Several important inferences may be drawn from the intimate relation between the floras of these two areas. Thus, the Maripósa formation, with which the Monte de Oro formation has been identified, is regarded by Stanton as referable to the late Jurassic, but if a considerable element of the Oroville flora occurs in Alaska in association with an invertebrate fauna acknowledged to be of Middle Jurassic age, it would seem to follow that the Mariposa is also of similar age. The interpretation of the bearing of the invertebrates on this question must naturally be left to the invertebrate paleontologists, but this much can be said: The plant evidence, as above stated, is distinctly in favor of regarding the Mariposa as much older than "late Jurassic."

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* Geol. Soc. Am., Bull., vol. xvi, p. 397, et seq., 1905.

Other localities in Alaska are as follows: From Herendeen Bay, in association with shells of *Aucella crassicollis*, we have *Pterophyllum alaskense* Font., a form very closely related to *P. rajmahalense*, in fact hardly to be separated from it. The latter species is one of the most abundant and important of those found in the Oregon locality. Near Nikolai in the Copper River region occurs *Sagenopteris alaskense* Font., which is near *S. Göppertiana* of the lower Oölite of Italy, and which is found also at Thompson Creek, Elk River and Oroville. From the vicinity of Cape Lisburne quite large collections have been obtained. These comprise 14 species which were considered by Fontaine to be of Jurasso-Cretaceous age, but a study of large additional collections since secured, together with a review of much of the original material, has convinced the writer that they are of the same age as the other Alaskan and Pacific Coast plant beds. About half of the Cape Lisburne species are identical with those of Oregon or California. The final locality is between Icy Cape and Wainwright Inlet, some 180 miles northeast of Cape Lisburne. This place has afforded *Podozamites* sp. and *Baiera gracilis*, the latter a species characteristic of the Yorkshire beds.

On account of the larger number of common species, the next area to be compared, although not logically next from a geographical point of view, is Yorkshire, England, which has in common with the California–Oregon region the following:

Marchantites erectus
Cladophlebis denticulata
Cladophlebis haiburnensis
Coniopteris hymenophylloides?
Thyrsopteris Murrayana
Ruffordia Göpperti
Tæniopteris major
Tæniopteris vittata
Sagenopteris paucifolia
Ptilozamites Leckenbyi
Pterophyllum minus
Nilsonia compta
Podozamites lanceolatus
Ctenis sulcicaulis
Cycadeospermum Bucklandii?
Ginkgo digitata
Taxites zamioides
Brachyphyllum mamillare
Pagiophyllum Williamsonis.

The flora of the Yorkshire beds has been made the subject of an exhaustive study by Seward,[*] published in 1900. The

[*] Cat. Mesoz. Pl. Brit. Mus., Jurassic Fl., I., Yorkshire Coast.

Jurassic forms a narrow band across England from Yorkshire to Dorsetshire, the plant-bearing beds being especially well represented in the vicinity of East Yorkshire. The area has been a favorite collecting ground for English students for nearly or quite a hundred years, with the result of bringing together a large amount of material. Professor Seward has re-studied such of the old type material as is now available, together with that of more recent date, and as a result has been able to give a very full and satisfactory account of this flora. The age of the Yorkshire plant beds has been very definitely fixed as Lower Oölite.

Certain of the species enumerated in the above list are very characteristic of the Yorkshire flora, such for instance as *Cladophlebis denticulata*, *Thyrsopteris Murrayana*, *Ptilozamites Leckenbyi*, *Nilsonia compta*, *Ctenis sulcicaulis*, *Brachyphyllum mamillare*, *Pagiophyllum Williamsonis*, etc. They are, for the most part, forms not likely to be misidentified, and therefore of especial importance in the present connection.

Jurassic plants are known from a number of localities in France, the more important being Mamers, D'Ethrochey, and Châteauroux, in the departments of Sarthe, Côte d'Or, and Indre, respectively. A considerable number of species are common to these French localities and the English beds just considered, while there are in common with the Pacific Coast at least the following:

Tæniopteris vittata
Brachyphyllum mamillare
Ginkgo digitata.

A single species (*Sagenopteris Göppertiana*) has been reported by Zigno from the Lower Oölite of Italy.

It is of interest to note that there are two species—*Pterophyllum contiguum* and *P. Nathorsti*—found in the Oregon beds that have previously been reported only from the Kweitschou beds of China. According to Schenk this horizon cannot be older than Lower Jurassic, and, as Fontaine has stated, since the beds contain *Podozamites lanceolatus* and *Nilsonia compta*, it is most likely that the age is Lower Oölite, certainly not younger. *Pterophyllum æquale* has been noted by Schenk in the Tumulu coal fields of China, in beds of Lower Oölitic age.

In the Kaga strata of Japan, which Yokayama refers to the Lower Oölite, we have *Nilsonia nipponensis*, a species represented by several fairly well preserved examples in the Oregon beds.

There are a few species in the Pacific Coast flora that have heretofore been found only in older beds. Thus, *Pterophyllum rajmahalense* was first found in the Rajmahal series of India, which is held to be of Liassic age, but as this does not differ apparently from Heer's *Pterophyllum sensinovianum* from the Jurassic of Siberia, if Heer's conclusion as to the age of the strata containing it is correct, it appears to have persisted into the Lower Oölite. It is one of the most important and abundant forms at a number of the Oregon localities, occurring literally in hundreds of specimens.

Another species regarded by Fontaine as possibly common to the Rajmahal series is *Cladophlebis indica*, though it is represented by a single example and thus is not of great importance, and the variety of *Didymosourus bindrabundensis* is but a slight variation from the species as known from these beds; it is also represented by a small fragment only.

The following species are believed to be common to the Rhaetic of Sweden: *Nilsonia pterophylloides* and *Pterophyllum æquale*, while portions of a plant have been identified as *Baiera multifida?* from the older Mesozoic (Rhaetic) of Virginia.

From this it appears that a few of the forms had their origin in older beds and persisted into this stage of the Jurassic, but none of those above enumerated is known to continue into higher horizons.

Having considered those species evidently older, it will be of interest to enumerate those continuing above the Jurassic. The following species have been found in Wealden, Neocomian, or higher beds:

Onychiopsis psilotoides
Ruffordia Göpperti
Podozamites lanceolatus
Ginkgo siberica or *digitata*
Sequoia Reichenbachi.

The species first mentioned, which was doubtfully identified in the beds at Big Bar, is a common species of the English Wealden, and forms suggestive of it, though they have often been given other names, occur in the lower Potomac of Virginia, the Cenomanian of Niederschöna, etc. *Ruffordia Göpperti* is likewise found in the Wealden of England. *Podozamites lanceolatus*, as Professor Fontaine has pointed out, is "probably a much abused type of leaf. It probably is not a species, but rather a type of leaf found in many species which lived in Jurassic times. The original is from the Lower Oölite and the form is probably more characteristic of that period than any other." Leaves that have been identified as belonging to this species have been found well up in the Cretaceous. *Ginkgo siberica* (or *digitata*) has already been discussed, while *Sequoia Reichenbachi* has been mentioned as the only species common to the Lower Cretaceous flora of California and Oregon. It ranges through the Cretaceous, principally in the upper part.

As has been so often stated, the mere presence of a species in a list is not all that is required to make it of value in fixing age. The plant must be abundant in a flora and characteristic of it. It may be a survivor from an older flora, or the first appearance of a form destined to become a dominant factor in a later horizon. It is for this reason that so much stress has been laid on relative abundance of species in the several parts of this paper, but to bring it out still more forcibly the following may be enumerated as filling such requirements:

Dicksonia oregonensis (close to *D. gracilis* Heer), *Polypodium oregonense*, *Tæniopteris orovillensis*, *Tæniopteris major*, *Tæniopteris vittata*, *Macrotæniopteris californica*, *Sagenopteris Göppertiana*, *Sagenopteris paucifolia*, *Nilsonia orientalis*, *Nilsonia parvula*, *Pterophyllum Nathorsti*, *Pterophyllum contiguum*, *Pterophyllum æquale*, *Pterophyllum rajmahalense*, *Podozamites lanceolatus*, *Ctenis sulcicaulis*, *Ginkgo digitata*, *Ginkgo Huttoni*, *Ginkgo lepida*, *Ginkgo siberica*, *Taxites zamioides*, *Brachyphyllum mamillare*. Certain of these exist literally in hundreds in the beds.

AGE OF THE "JURASSIC FLORA OF OREGON."

Following is Professor Fontaine's* final opinion regarding the age of the beds containing the Jurassic flora: "There can be no doubt, in the opinion of the present writer, that the Yorkshire Lower Oölites, the strata of eastern Siberia and of the Amour, made known by Heer, and the Oregon beds are of the same age. The only question is, What is that age? The investigations of the English geologists would seem to have settled the question for the Yorkshire formation. . . . So far as my knowledge goes, no one has questioned the correctness of the conclusions of the English geologists regarding the age of the Yorkshire strata. That being established as Lower Oölite would certainly indicate a similar age for the Siberian beds and also for those of Oregon."

The facts that have been presented in the preceding pages regarding relative abundance and world distribution prove beyond any reasonable question that the above statement is correct, and it is confidently asserted that the "Jurassic flora of Oregon" is a true Jurassic flora. This age determination has been held by the writer for some years; in fact all original as well as subsequent collections have tended to prove it, as they have also the distinctness of the Jurassic and Cretaceous floras of the region. I have, however, ventured to submit the question to Prof. A. G. Nathorst of Stockholm, who is perhaps the greatest living authority on the Jurassic floras of the world. His comment is as follows: "As to the 'Jurassic flora' of Douglas County, Oregon, I can but think that the American paleobotanists are *right* in regarding it as a true Jurassic flora. For even if some of the specific determinations are incorrect, this has no influence on the question of age. *If*, therefore, the *same* flora is found in California, it is naturally also of Jurassic age. In this matter I do not think it possible that there can be more than one opinion prevailing among paleobotanists."

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* U. S. Geol. Surv., Mon. 48, 1905, p. 144.

A COMPARISON OF THE JURASSIC AND LOWER CRETACEOUS FLORAS OF THE OREGON–CALIFORNIA AREAS.

If these two floras comprised a small number of species each, it could be argued that lack of identical forms might be corrected by more extensive collections, but fortunately both floras are relatively large, the Jurassic embracing 100 and the Lower Cretaceous 59 forms. Most of the localities have been extensively—even exhaustively—exploited, and the numbers are sufficiently large to bring out the interrelationship if such existed. An examination of the two lists, however, shows that there is only a single species (*Sequoia Reichenbachi*) common to the two, and as this species is of very wide vertical range, it would seem to be settled conclusively that there is no real relationship between the Jurassic and Lower Cretaceous floras. This conclusion is made more positive and significant by the fact that in certain localities, as near Riddles, they occur practically in the same section. That they may yet be found commingled in the same beds is a contingency that seems highly improbable, though that the Jurassic flora may sometime be found in the lower part of the Knoxville of the Sacramento Valley, below the Lower Cretaceous flora and fauna, is quite possible.

It is not within the scope of the present paper to enter into an exhaustive discussion of the Lower Cretaceous flora of California and Oregon beyond the general statement of its obvious affinities. To some extent this has already been done by Professor Fontaine.*

EVIDENCE OF THE INVERTEBRATES.

As stated in the opening paragraphs of this paper, it is not the intention to enter into a critical analysis of the invertebrate faunas, as the writer does not feel competent to do this, but simply to point out certain salient facts regarding their distribution and interpretation. In the first place, to mention briefly the invertebrate faunas associated with the Lower Cretaceous flora of California and Oregon, it may be observed that there is no conflict between the two lines of evidence. Thus, near Riddles, Oregon, as Mr. Diller says: "Both fauna and flora agree with the stratigraphy in correlating this area of the 'Myrtle' with the Shasta on the western side of the Sacramento Valley." In the area on Redding Creek, California, the shells are regarded as being of lower Horsetown age, which agrees with the Shasta age of the plants, while concerning the numerous localities on the western side of the Sacramento Valley, the plants and shells are again in accord with the stratigraphy as regards the position and identity of the beds. That they are of Lower Cretaceous age no one appears to question.

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* U. S. Geol. Surv., Mon. 48, pp. 270–273, 1905.

Turning now to the areas which have supplied the Jurassic flora, we find that at Thompson Creek the only invertebrate evidence is a fragment that may not even be a shell. At Buck Peak the nearest plant horizon is 1200 feet below the point at the summit where *Aucella crassicollis* is found, though only a short distance below a conglomerate containing *Aucella Piochii.* The only plant found in the intervening beds—and this a mere fragment—occurs near Riddles, also in association with shells of *Aucella Piochii.* From the area near Nichols Station, one of the most important of the plant localities, a single example of *Aucella Piochii* is reported, but it was not found in place and it is not known that it even came from the plant beds, though possibly it did. In the beds at Rattlesnake Creek, the only invertebrate evidence reported is that of "two small shells which appear to be young specimens of Unio, though they may belong to some marine genus instead"; obviously they are not of importance in fixing the age.

There remain for consideration but three localities at which a fauna has been found in direct and positive association with the Jurassic flora. First, that at Oroville, California, where the invertebrates, while not abundant or very well preserved, are regarded as "more probably" belonging to the Mariposa, with a suggestion of the resemblance to the older Jurassic faunas of the Taylorsville region. Here again fauna, flora and stratigraphy are in agreement. It finally resolves that Big Bar, California, and Elk River, Oregon, are the only localities at which flora and fauna are apparently not in accord. The only named invertebrate found at the first mentioned locality is *Aucella crassicollis.* Concerning this and the unnamed or unidentifiable forms found with it, Doctor Stanton reports as follows: "The fossils from Big Bar, California, area are certainly upper Knoxville, and hence Lower Cretaceous, as shown by the presence of typical specimens of *Aucella crassicollis.* The other invertebrate fossils from the same area are closely associated stratigraphically with the Aucella, but as they are either undescribed or unidentifiable species, they do not throw any additional light on the question of the age of the beds."

On combining the faunas of Big Bar and Elk River there are found seven named species, of which the most important and characteristic is regarded as *Aucella crassicollis*, which Doctor Stanton says "past experience shows to be characteristic of the upper part of the Knoxville formation, and is believed to be confined to the Lower Cretaceous."

The new facts regarding the distribution of the several species of Aucella in the section at Elk River, which resulted from Mr. Diller's re-examination of the area during the past summer and which has already been briefly alluded to [p. 37], is of much significance in the present connection. From this evidence it appears that not only is the principal horizon for *Aucella crassicollis* in the basal member of the Knoxville and *beneath* that of the Jurassic plant beds, but *Aucella Piochii*, supposed to characterize the lower portion of the Knoxville—indeed so occurring in the Elk River section—has been found in the underlying slates of probable Dothan age in association with *Aucella Erringtoni*, which is a typical Mariposa species! The wide vertical range here shown for *Aucella crassicollis* and *A. Piochii* would certainly seem to disqualify them as diagnostic or key fossils.

The interpretation that is to be given the Knoxville fauna as a whole may now be considered, and it requires only a brief review of the literature to show that the invertebrate paleontologists are not in agreement among themselves as to what this shall be. Thus, Doctor Stanton* regards the entire fauna of the Knoxville formation as of Neocomian age. After reviewing the differences of opinion regarding the age of certain Russian beds, he continues: "It is evident, then, that even if it were possible to refer the Knoxville to definite horizons of the Russian Aucella beds, its age might still be questioned. One important fact that should be borne in mind is that structurally and faunally, so far as known, the Knoxville is a unit. It is true that there is a gradual change in the fauna from the lower to the upper beds, but there is no distinct break that would justify the reference of one portion to the Jurassic and another to the Cretaceous. There are some elements of the fauna, such as *Belemnites tehamaensis*, *Hoplites Storrsii*, and some of the Turbinidæ, that resemble European Upper Jurassic types. *Aucella Piochii* belongs to the same general type as *A. mosquensis*, which has usually been referred to the Jurassic, and it is somewhat closely related to the Aucellæ of the Mariposa beds; but Professor Pavlow informs me that Aucellæ very similar to *A. mosquensis* occur in the Neocomian of Russia also. These resemblances . . . . . . are not considered of sufficient importance to counterbalance the evidence of the Cretaceous age of the entire series. Some Jurassic elements are naturally to be expected in the Lower Neocomian, and it is well known that in Europe several species of ammonites pass up from the Jurassic to the lowest Cretaceous beds."

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* U. S. Geol. Surv., Bull. 133, p. 30, 1895.

On the other hand, Prof. A. P. Pavlow,* the distinguished Russian geologist and paleontologist, in reviewing the Knoxville species of Aucella, takes issue with Doctor Stanton as to the age of the beds. He says: "I share perfectly the opinion of Diller and Stanton that the different parts of the Knoxville series contains each its own Aucella fauna, which becomes modified gradually. But I cannot share the opinion that all the Knoxville ought to be referred to the Cretaceous system. At least in that which concerns its lower part characterized by *Aucella Gabbi* (*Aucella Piochii* type) I do not find data sufficient to take this side, since the Aucella beds speak more in favor of placing these lower beds in the Portlandian, or perhaps in the Aquilonian (though for this last there are only a few indications). The upper part of the series, which is the larger (2000 feet), offers an Aucella fauna of the character of the Lower Cretaceous."

If this view be accepted—and it may be added that it corresponds well with the plant evidence—the Knoxville will be divided into two parts, of which only the upper (2000′±) will be Cretaceous, while the remainder (18,000′) of the great section will be relegated to the Jurassic. Professor Pavlow was of course unaware of the fact that the two species of Aucella (*A. Piochii* and *A. crassicollis*) overlap in range to the extent just shown at Elk River and elsewhere, and the deciding factor in drawing the Jurasso-Cretaceous line may well be the floras.

Another one to write upon the subject is Dr. Emil Haug† of Paris, who, after enumerating a number of Knoxville forms, which he says "have for a long time been parallelized with the Neocomian of Europe," proceeds as follows: "However, the work of Mr. Stanton contains also several *Hoplites*, described as new species, but which are close neighbors of species of the horizon of Stramberg, some among them being even very probably identical with these last. There can be no doubt that the lower part of the "Knoxville beds" corresponds to the upper Portlandian of the Mediterranean region."

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* Nuov. Mém. Soc. Impér. Nat. Moscow, vol. xvii, p. 83, 1907.

† Bull. Geol. Soc. France (3), vol. xxvi, p. 226, 1898.

This view is even more revolutionary than that of Professor Pavlow, since if the genus *Hoplites*, as represented in the Knoxville, is taken as the gauge of Jurassic age, it will carry with it practically the entire Knoxville fauna, which is found in direct association with one or the other of the five species recognized in this genus.

More recently still Prof. James Perrin Smith, in an article on "Salient Events in the Geologic History of California,"* has expressed his conviction, based on invertebrate as well as stratigraphic evidence, that the line between Jurassic and Cretaceous shall be drawn through the Knoxville and not at its base. He says: "After this mountain-making epoch near the close of the Jurassic, the sea again encroached on the uplifted area, and the Knoxville sediments were laid down on the western border of the Coast Range. The lower Knoxville beds contain a fauna closely related to that of the Mariposa, still with Jurassic types of Aucella, and with the same poverty of other animals. But the upper Knoxville beds, while still retaining reminiscences of the Boreal Region in *Aucella* and a few other forms, show a preponderance of life characteristic of more favorable conditions. Aucellas of more northerly habit mingle with cephalopods that did not belong in the Boreal Region, and on the nearby land cycads abounded. The line between Jurassic and Cretaceous should be drawn, not at the beginning of the Knoxville but between the lower and upper Knoxville beds; the former belonging to the Portland and Aquilonian, while the latter belong to the Neocomian."

Enough has been presented to show that there is more or less difference of opinion regarding the bearing of the invertebrates of the Knoxville on the question of age.

Relations between Myrtle and Knoxville.

The Myrtle formation takes its name from what is regarded as its typical exposures along Myrtle Creek, Oregon, in the Roseburg quadrangle. In this general area the maximum thickness of the Myrtle formation is estimated by Mr. Diller to be about 6000 feet. It is separated on paleontological grounds into two portions, the later (upper) of which from its contained invertebrate fauna was correlated with the Horsetown of California, while the earlier (basal) portion was correlated with the Knoxville on the basis of the presence of certain invertebrates but especially *Aucella crassicollis* and

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* Science, N. S., vol. xxx, pp. 347, 348, Sept. 10, 1909.

Aucella Piochii. The first mentioned species of Aucella, Mr. Diller says,* "is characteristic of the later portion of the Aucella-bearing beds immediately adjoining the Horsetown beds. In California these forms are found in the Knoxville beds, which lie below and are older than the Horsetown beds."

In his latest published words on the relations of the Myrtle formation Mr. Diller continues as follows:† "At the base of the 'Myrtle formation' in Oregon there is an important unconformity and overlap. The successively newer, overlying strata of the 'Myrtle' in general lap over further and further inland beyond the limit of the older strata of the same series, just as the members of the Shasta series do in California. Furthermore, the lower portion and greater part of the 'Myrtle formation' is characterized by a fauna in large measure identical with that of the Knoxville beds, while the top part contains a fauna closely related to that of the Horsetown beds. There is good reason, therefore, for regarding the Shasta series of California and the 'Myrtle formation' of Oregon as equivalent."

To this statement there is but one conclusion possible, namely—that Mr. Diller regards the Myrtle as a whole as the equivalent of the Shasta as a whole, the latter naturally including both Knoxville and Horsetown. As the newer part of the "Myrtle formation" corresponds to the Horsetown, so the earlier part corresponds to the Knoxville. That this earlier portion of the Myrtle really corresponds to the whole of the Knoxville is shown, as at Elk River, Thompson Creek, etc., by the presence in it of a Jurassic flora, and *Aucella Piochii*, which latter is held to characterize the lower Knoxville. On the other hand, from the presence of *Aucella crassicollis* in association with the Jurassic plants in this earlier portion of the Myrtle, the whole of this portion is held by some to be equivalent to the upper part of the Knoxville just below the Horsetown—in other words, that there is nothing in the Myrtle section corresponding to the middle and lower portions of the great Knoxville section. This view would seem to involve some paleontologic, as well as stratigraphic, difficulties or anomalies. First—If the lower portion of the Myrtle corresponds only to the upper part of the Knoxville, then it is hardly correct to say that the Myrtle as a whole is the equivalent of the Shasta as a whole. Second—As already pointed out, Louderbach, on structural and lithologic grounds, regards the lower portion of the Myrtle as referable to the Franciscan of California. To correlate this with the upper part of the Knoxville would certainly do violence to this view. Third—

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* Roseburg folio, No. 48, p. 2, 1898.

† Geol. Soc. Am., Bull., vol. xix, p. 396, 1908.

A choice must be made between the evidence afforded by the two species of Aucella, since these are regarded as the most important and characteristic of the invertebrates. If *Aucella crassicollis* is selected, then this portion of the Myrtle will be upper Knoxville; if *Aucella Piochii* is followed, this portion may be lower Knoxville. In this connection it is to be remembered that in certain sections of the Myrtle—such, for instance, as that at Elk River—*Aucella crassicollis* occurs above, commingled with, as well as below, the Jurassic plants, while here or in nearby areas *Aucella Piochii* is found also below, with and above the plants.

In view of these conflicting alternatives it seems to the writer that the plants, being thoroughly consistent, afford the better criteria, and on their evidence the earlier portion of the Myrtle is regarded as representing the Jurassic portion of the Knoxville as a whole. If this be true, and it is believed to be, then *Aucella crassicollis* ranged from near the base of the Knoxville (Myrtle) to near its top.

As affording a possible confirmation of the position above assigned the Myrtle on the basis of the plants, a word may be said regarding a comparison of the depositional conditions under which the Myrtle and Knoxville were laid down. It needs but a glance at the geological folios involving the areas covered by the Myrtle formation (Port Orford, Coos Bay and Roseburg quadrangles) to show that during Myrtle time there was a broad bay, or estuary, opening on the west to the Pacific ocean, and extending northeast as far at least as the middle of the Roseburg quadrangle. In the Sacramento valley in Knoxville time there was similarly a bay opening on the south and extending northward between the Coast Range and the Sierra Nevada. In both areas there was a progressive subsidence and decided overlap. In the Myrtle area this extended northeast and was most marked in the Riddles area. In the Sacramento Valley it of course proceeded northward, first the Knoxville, then Horsetown, and finally Chico, resting successively on older rocks. So far as known to the writer there is no *a priori* reason why these two bays may not have been practically synchronous. It will probably never be possible to settle this point stratigraphically, since it is highly improbable that these were at first, if indeed ever, connected on the present land mass.

That the Myrtle formation, as thus far made known, corresponds only to the upper part of the Knoxville, while the still earlier lower portions are concealed beneath the sea, or may yet be found in some unexplored portion of Oregon, is to beg the question.

RELATIONS BETWEEN KNOXVILLE AND MARIPOSA.

The evidence that has been presented regarding the Jurassic flora and its distribution obviously has a bearing on the relations between the Knoxville and the Mariposa. As is well known, Dr. C. A. White held that the Knoxville and Mariposa were contemporaneous, at least in part, a view fully accepted by Doctor Becker, though not generally agreed to by subsequent workers in this field. The two formations have never been found in contact, nor are they likely to be, since one (Mariposa) is found on the western slope of the Sierra Nevada in central California, and the other (Knoxville) on the opposite side of the Sacramento Valley, mainly against the eastern slope of the Coast Range. A strong point of agreement is shown by the abundance of Aucellæ in both, though they are not now admitted to belong to a single species, as Doctor White believed. Doctor Stanton states that "the faunas, though not large, are entirely distinct, and that of the Mariposa includes several forms of ammonites that are characteristic of late Jurassic the world over, while that of the upper part of the Knoxville contains an equally characteristic array of Cretaceous forms." It is not surprising that there should be a marked difference between the fauna of the Mariposa and the *upper part* of the Knoxville, but when the comparison is made with the lower Knoxville, according to Prof. James Perrin Smith, it shows "a fauna closely related to that of the Mariposa, still with Jurassic types of Aucella." As a matter of fact practically the entire Knoxville fauna, with the exception of Aucella, has come from the upper 3,000 feet of beds, that is the beds within this distance of the upper range of *Aucella crassicollis*, which is fixed as the point separating Knoxville from Horsetown. As thus delimited it comprises a sufficiently distinct faunal group (the Paskenta division of Anderson), but its extension to include the underlying 17,000± feet of beds which contain exceedingly few of the Knoxville species other than Aucella, is seemingly without adequate support.

Be this as it may, the relation, if it exists, is through the flora of the Monte de Oro formation near Oroville, which "on geographic and structural as well as lithologic and economic grounds" has been correlated with the Mariposa. The Oroville flora, as already shown, binds it inseparably with the other Jurassic plant-bearing areas in California and Oregon, and as pointed out on p. 49, the finding of five characteristic Oroville plants in the Middle Jurassic of the Cook Inlet region is certainly a strong indication that the Mariposa (Monte de Oro) is not the latest Jurassic.

The intense folding, vulcanism and partial metamorphism of the Mariposa is held to be a strong indication of its greater age as compared with the Knoxville, where there has been comparatively little folding or other alteration; yet even this should apparently be accepted with a measure of caution, since it is by no means clear that the various students who have worked in this field have always given the same limits to the Knoxville. Thus the Dillard area of Oregon seems to be more or less of an exception. In this area the rocks have undergone silicification and veining similar to that of the Mariposa, and on these lithologic as well as other grounds are regarded by Louderbach as identical with the Franciscan of California, which is almost certainly the approximate equivalent of the Mariposa, if not indeed below it. However, from the presence in the rocks of the Dillard area of two species of Aucella (*A. Piochii* and *A. crassicollis*), Diller considers them referable to the Myrtle (Knoxville). But since the shells occur in calcareous pebbles in a conglomerate it is possible that they were derived from an earlier Aucella-bearing horizon, though it is but fair to state that Diller concludes that they may be concretions rather than true rolled pebbles.

RELATIONS BETWEEN DOTHAN AND MARIPOSA.

In the Oregon areas here considered the Jurassic plant beds are unconformably underlain in many places by rocks to which the name Dothan formation has been given, and these in turn have been tentatively correlated with the Franciscan of California. The Dothan rocks, chiefly sandstones with some slates, which have been more or less silicified and veined, are characterized by the presence of *Aucella Erringtoni*, a species found also in the Mariposa. The only plant thus far noted in the Dothan was found on Catching Creek, about six miles southwest of Riddles, and was identified as probably the upper part of a leaf of Pterophyllum, such, for example, as *P. æquale* (Brongn.) Nath. Although this is so fragmentary as to be of little value in fixing the age, it is nevertheless a suggestion that if a flora could be developed in these beds, it would more than likely bring out a similarity to that of the Oroville (Monte de Oro) flora.

THE LINE BETWEEN THE JURASSIC AND THE CRETACEOUS.

It has been held on structural and stratigraphic grounds, that in this area the line between Jurassic and Cretaceous should be drawn at the base of the Knoxville. However, the paleobotanical evidence that has been presented in this paper shows that, notwithstanding the unconformable relations existing between the Knoxville and underlying beds, this is not a natural line of delimination. According to the plants the major portion of the great Knoxville section was deposited in Jurassic time, and the line should be drawn through the upper Knoxville at the highest point (about 2000 ± feet below the summit) at which the Jurassic flora occurs. This point corresponds very nearly with the upper limit of the range of *Aucella Piochii*, which is acknowledged to be of Jurassic type, and, as already shown, extends down into the horizon of the Mariposa. It is true that this places the line at a point where there is no evidence of a break in the sedimentation, but it is a very decided paleontological break, and is exactly similar in character to that relied upon to separate Knoxville from Horsetown in the same section. Although the Knoxville is of such great thickness (20,000 feet), it is not probable that it required a very long time, geologically speaking, for its deposition.

SUMMARY.

1. The Lower Mesozoic strata of Oregon and California have afforded two floras, one of which is Cretaceous and the other Jurassic. These two floras, although sometimes occurring practically in the same section, have not been found commingling.

2. The Cretaceous flora ranges from the extreme upper part of the Knoxville formation through the Horsetown formation. It embraces about 60 species of plants and is regarded as being of Lower Cretaceous (Neocomian) age. It finds its closest affinity with the Kootenai of the Interior region, the Trinity of Texas, and the lower Potomac of the Atlantic Coast.

3. Associated with the Lower Cretaceous flora is an invertebrate fauna regarded as being of Neocomian age, the plants and invertebrates thus being in agreement.

4. The Jurassic flora, which has been called the "Jurassic flora of Oregon," ranges from beds which have been referred to the Mariposa formation, through the major portion of the Knoxville formation. It includes 100 species and finds its close affinity with the Lower Oölite floras of known position in other parts of the world. It is beyond question a true Jurassic flora.

5. Associated with the Jurassic flora is a meager, often poorly preserved, invertebrate fauna of only seven species, including the two supposedly characteristic species of Aucella (*A. crassicollis* and *A. Piochii*). This fauna, with the exception of *Aucella Piochii*, is the same as that found in association with the Lower Cretaceous flora, and it is on account of this association that the Jurassic plant beds have been referred by some invertebrate paleontologists to the Cretaceous.

6. The age of the beds containing the "Jurassic flora of Oregon" thus hinges on the relative strength of the evidence afforded by the flora as compared with that of the associated fauna. It has been shown in this paper that of a total of 100 species of plants, 47 species are known also from known Jurassic of other, often widely separated, parts of the world. Only one of these 100 species has been found in the Lower Cretaceous beds of the region. The total Knoxville fauna comprises 77 forms of invertebrates, only 7 named species of which have been found associated with the Jurassic plants. Of these 7 species of invertebrates, only a single species has been found outside the limits of the Oregon-California area, and it has been further shown that the invertebrate paleontologists are not in accord among themselves as to the interpretation to be given the age determination of the fauna. The conclusion is reached that the plants, being thoroughly consistent, afford the better criteria, and the beds are regarded as unquestionably of Jurassic age.

7. From the paleobotanical evidence which has been presented it follows that in this portion of the Pacific Coast region the line between the Jurassic and Cretaceous is to be drawn through the upper part of the Knoxville formation, and not at its base. This line is fixed by the upper limit of the Jurassic flora.

Art. V.—*Geologic Bearing of the Peat Beds of Anticosti Island;* by W. H. Twenhofel.

[Contributions from the Paleontological Laboratory of Yale University.]

Introduction.

Inferences as to the method of deposition of the vegetable matter forming coal have developed two rival hypotheses: the one arguing for deposition of the vegetable matter after transportation; the other for deposition by growth in place. The former hypothesis has had its ablest supporters in France, where the close association of coal beds with transported deposits and the character of the coal itself lend aid to that view. The latter hypothesis has been and is most favored in America, England and Germany. In many cases more extended studies have reduced in numbers the coal beds believed to have resulted from deposition after transportation.

The climate of coal-forming times has been a subject concerning which geologists have held and hold different views. Most that has been written on this question has sought to show that a luxuriant vegetation existed at such times and that such has required a warm climate for its development. From time to time doubt has been cast on that view, yet it apparently remains almost universally accepted at the present time.

It is the purpose of this article to endeavor to give additional facts bearing on the method of deposition of the coal and on the climate of past coal-forming times. The writer wishes to acknowledge his obligations to Professors Charles Schuchert and Joseph Barrell for advice and criticism in the preparation of the paper.

Coal beds in association with marine deposits and resting directly on limestones of marine origin have been reported from various portions of the coal fields of the United States,* but to the writer's knowledge practically nothing has been offered in explanation of the origin of such formations. In the case described by Winslow the coal is of the cannel variety, which is ordinarily assumed to have been deposited by water in a quiet basin and subjected to prolonged leaching;† but in this case it lies in an erosion channel. Coal beds of this character find a ready explanation, other facts being neglected, by deposition after transportation. Greater difficulty of explanation arises if a continental origin by growth in place be assumed.

In the following pages such a coal bed now forming will be described, and a brief discussion will be given of the conditions under which it is developing.

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* 22d Ann. Rep. U. S. Geol. Surv., pp. 175, 181, 216, 1901. Winslow, Arthur, Prelim. Rep. on Coal, Mo. Geol. Surv., p. 170, 1891.

† Dana, J. D., Manual of Geology, 4th ed., p. 710, 1895.

While engaged in the summer of 1909 in studying, in the interest of the Peabody Museum of Yale University, the Ordovician and Silurian strata of Anticosti Island, the writer had his attention frequently attracted to the peat deposits which are forming on nearly all parts of the island's surface. This island is situated in the northern half of the Gulf of St. Lawrence between 49° 4′ and 49° 53′ north latitude. Its surface consists of a series of flat and poorly drained raised terraces which are backed by sea-cliffs of relatively recent age.

The examination covered the entire coastal portions and several parts of the interior, an area with a maximum length of one hundred and forty miles and a maximum width of a little more than thirty-four miles.

Description of the Deposits.

The Peat.—The peat deposits of this island, said to be the greatest in Canada,* are practically coextensive with the island's surface. Thicknesses vary from two to ten feet, the minimum thicknesses existing on the slopes of the upland areas where the drainage is best and where decay has advanced farther so that more earthy matter is present. The maximum thicknesses and best quality are found on the lowest terrace and flat, or nearly flat, portions of the higher terraces. On many areas the peat is very black, well compressed and of good quality, showing microscopically few traces of the original vegetation. On other areas it is less compact, of a more or less brown color, and much undecayed matter is present. Both varieties often exist in the same bed and woody matter may range from top to bottom.

On the eastern two-thirds of the south coast for about eighty miles the lowest terrace is two or more miles wide and here the peat reaches its greatest development as a thick deposit, thicknesses of more than ten feet being common. Numerous other areas of from one hundred to more than a thousand acres, where a thickness of about ten feet exists, occur at all altitudes.

In many places the surface of the peat beds is marked by low ridges and hillocks and in the lower portions of such beds undulations duplicating these appear, but somewhat more gentle in outline. Such are well shown in the vicinity of Chaloupe Creek, about sixty miles from the east end of the island, where on cross-section a ripple-mark effect is produced. It is believed that the irregularities of the upper surface are produced by differential growth of vegetation, these irregularities under compression tending to flatten out.

Substratum of the Peat Beds.—The substratum on which the peat rests consists of Ordovician and Silurian limestones and shales with an approximately level eroded surface, the beds dipping southward from less than one to about six degrees. Lying upon these strata in limited areas, but so far as known to the writer, on the south side only, are stratified beds of Pleistocene or more recent clays that are of marine origin, as indicated by the presence of *Mya arenaria* in abundance. A small angular unconformity, difficult to determine on small exposures, separates the two deposits.

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* Logan, W. E., Rep. of Progress, Can. Geol. Surv., p. 783, 1863.

Overlying portions of these clay deposits conformably, so far as known, are beds of stratified sand and gravel ranging in some places up to more than fifty feet in thickness and holding at different horizons lenses of clay. In some localities the sand apparently rests on the limestones. Pebbles and bowlders of glacial origin are present in both clay and gravel.

Overlying the clay, gravel, and sand, and the limestones where these are wanting, is a thin veneer of limestone gravel, which is apparently of beach origin. Overlying this are the peat beds producing another unconformity. These two unconformities would, after burial, be difficult to detect at small exposures, unless such were transverse to the old cliffs, and fossil evidence would be the chief criterion for their determination.

Marine Fossils in the Peat Beds.—On the lowest terrace, shells of marine organisms, such as sea-urchins, fragments of lobsters and crabs, gastropods, etc., are exceedingly common; being brought there by birds, chiefly crows, and more rarely, but in greater numbers, by waves of storms. Many examples of the latter case can be seen at different points along the south shore, where hundreds of sea-urchins have been washed upon the seaward edge of the marsh.* These must exist in the peat beds of the lowest terrace, and as each of the higher terraces at one time held the position of the now lowest terrace, they should also be found in them although none were seen.

Conditions of Formation.

Character of the Vegetation.—The conditions that have permitted the development of these extensive peat deposits without an underlying soil are due to a combination of conditions none of which are uncommon. The greater portion of the island is covered with a low, dense, chiefly coniferous forest growth, so dense in many places as to be almost impenetrable. The absence of a soil does not permit the trees to gain a firm foothold, while the vast amount of water in the substratum has forced a horizontal development of roots. The foothold of the trees is, therefore, in most cases a very precarious one. The result is that the winds, always prevalent and usually strong, blow most of them down before a great height is attained unless they occupy more or less sheltered areas. The writer has seen one locality where fully a dozen half-grown trees had gone down together, the entire substratum being uplifted as a floor. In a wind this substratum can be felt to heave underneath one's feet.

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* **On the marsh about six miles west of Chaloupe Creek bushels of the common sea-urchin (*Strongylocentrotus dröbachiensis*) were seen.**

Some areas of the lowest terrace are treeless, the vegetation in most cases consisting of mosses, grasses, orchids, ground-pines, and similar low plants. Other treeless areas have a tangled growth of procumbent and low shrubs which are penetrable with the greatest difficulty. Among such shrubs a low spreading conifer is especially prominent, in many places effectually shielding even cliff slopes from the sun. Portions that are more or less covered with water are not lacking in a heavy growth of vegetation.

The rank luxuriance of the vegetation was a source of surprise. The annual growth rapidly springs up in wonderful profusion, while an open forest growth is not favored, due to the elimination of most of the large trees. This annual growth is added to the peat in the early part of September in a relatively short period of time and at a time when the absence of heat and superabundance of water prohibit oxidation. The writer believes that too great emphasis cannot be placed upon the fact that here in a relatively cold climate there exists a heavy annual growth of vegetation which is yearly added to the deposits of peat under conditions that practically prohibit its oxidation.

A comparison with the vegetation of such tropical regions as are exemplified by the Amazon valley would show that at any one time a greater quantity of vegetation exists in a definite region than exists on an equal area of Anticosti; but it is questionable if such a great increment is annually given to the substratum in the former region as in the latter, while in the former region the death of the vegetation extends over a long period of time under conditions that permit its ready destruction. The point upon which emphasis is desired to be laid is not, however, the abundance of vegetation; but the quantity that is not oxidized.

Climatic Conditions.—The climate is cool and moist. The temperature varied in the six years extending from 1897 to 1902* from 26° C., which occurred once, to −39° C., which occurred twice. The average temperature of June, July, and August is about 12·5° C.; that of the winter months is about 10° C. in the negative sense. The average annual temperature is about 2° C.†

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* Schmitt, Joseph, Monographie de l'Ile d'Anticosti, pp. 40–43, Paris, 1904.

† Ham, J., Isotherms of North America, Bartholmew's Physical Atlas, pl. 7, 1899.

The precipitation in the form of rain in the three months of the growing season varies from twenty-three to twenty-eight centimeters.* This does not appear to fall in a few heavy downpours, but in small quantities and often. The mean annual rainfall lies between fifty and one hundred centimeters, but is nearer the latter figure.† The snowy precipitation ranges from an average of three feet at the west end to about two feet at the east end.‡ Cloudiness and fogginess often prevail. The island lies in that region of North America that has the second highest per cent of clouded sky. The mean annual sunshine consists of less than 1750 hours.§ Fogs are extremely common on the east and south sides, as is shown by the fact that Mr. Emile Laprise, the South Point light-keeper, sounded the fog alarm on twenty-six days in July, 1909.

The water is collected in the numerous lakes and ponds, which abound everywhere from the lowest to the highest levels, as well as in the bogs and vegetable deposits. The falling water is absorbed by the substratum and little immediate flow results to swell the creeks and rivers, which were at no time seen in a muddy condition. They have, however, a steady permanent flow. Nearly every rock outcrop is a spring. At the old and new sea cliffs nearly every joint and many bedding planes are pouring forth water, a fact which will be rather strongly impressed in the experience of any one who attempts to collect fossils from these cliffs.

During more than seven months of the year the whole is ice bound; during the remainder of the year, except the early spring time before the annuals appear, the whole is effectually shielded by the profuse growth of annuals aided by the evergreen cover. Oxidation cannot occur, or at least is extremely limited, during the summer season and is hardly possible when the whole is ice bound and covered with snow.

Topographic Conditions.—The island's surface has been described as a series of flat, wave-cut terraces.‖ This level floor has favored the development of undrained areas. The highest terrace, which is more or less dissected, has an elevation above three hundred and fifty feet; the lowest is between eight and fifteen feet above high tide. Inferences as to the possible increased future extent of the deposits may be founded on the following facts: The island is surrounded by a wave-cut terrace upon which vegetation is wanting. This is now a part of the littoral, reaches a maximum width of more than two miles, and will average more than one-fourth mile. There is considerable evidence to show that the island is in a process of elevation with respect to sea level. Should this continue, vegetation will take possession of the then elevated terrace and a belt more than two hundred and eighty miles long with an average width given above will be given over to the formation of peat.

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* Schmitt, idem, p. 50.

† Herbertson, A. J., Bartholmew's Atlas, pl. 18, 1899.

‡ Schmitt, idem, p. 51.

§ Van Bebber, J. W., Bartholmew's Phys. Atlas, pl. 18, 1899.

‖ This statement is known to be correct for the major portion of the island. In the extreme interior it may not be true.

Inferences of Origin after Burial.

These deposits if entombed and metamorphosed into coal will contain land and marine fossils, the latter perhaps being greater in number; at least, remains of marine organisms are most often seen on the surface of the lowest terrace. They will lie between marine deposits from which they will be separated by unconformities representing great time intervals and difficult to detect except in sections transverse to the old sea cliffs. They will abut against these old cliffs, of whose origin there will be no question, and will have much appearance of having been deposited at their bases by transportation. Few trees will stand upright. Most will lie flat. Some may be found with roots upward. The biennial alternations of thawing and freezing will have macerated the leaves so that few perfect ones will remain. The helter-skelter and tangled masses of downfallen trees that are now common, if preserved, will simulate the appearance resulting from transportation. The undulations of the peat beds may even lead to the assumption that they are due to ripples. From another standpoint the profuse development of vegetation may be taken as evidence of a genial climate.

Conclusions.

The peat beds of this island and the magnificent growth of vegetation have strongly impressed on the writer the fact that a relatively cold climate may support a wonderful luxuriance of plant growth, providing the rainfall be sufficient, and that a warm climate is not an essential condition for the great accumulation of vegetable matter. This fact was recognized as early as 1835 by Darwin, who states: "In Terra del Fuego trees grow only on the hill-sides; every level piece of land being invariably covered by a thick bed of peat. * * * The climate of the southern part of America appears particularly favorable to the production of peat. In the Falkland Islands almost every kind of plant, even the coarse grass which covers the whole surface of the land, becomes converted to this substance; scarcely any situation checks the growth."*

From the polar side of the northern hemisphere Russell describes the tundra of the northern part of Alaska as covering "the whole surface, excepting the faces of steep cliffs and the summits of high mountains," and says that "a depth of 150 to 300 feet has been assigned to it where it is exposed in a sea cliff at the head of Kotzebue sound." He further states: "On the flood plains of the larger rivers and generally throughout all of Alaska, peaty deposits are forming in the same manner as on the tundra, modified, however, by the growth of arborescent vegetation and by the intrusion of sand and clay in places that are flooded during the high-water stage of the rivers." Russell suggests that such may have been the origin of some of our present coal deposits, which is further reinforced by the statement that the flora of the tundra is essentially cryptogamic and that "two species of Equisetum which may be considered as representing the Calamites of former times flourish in rank luxuriance over greater areas of the Yukon."*

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* Naturalist's Voyage Round the World, 1835.

Instances of enormous peat deposits in the polar halves of the temperate zones could be multiplied to great extent, while instances of such in the warmer regions are few or wanting, Schimper stating that peat does not form in the tropics except on mountains over 1200 meters high.†

Nor are examples confined to the present; for David notes the occurrence in New South Wales "of a group of Coal Measures, over 230 feet thick, and comprising from 20 to 40 feet in thickness of coal (the Greta Coal Measures)" being "sandwiched in between the erratic-bearing horizon of the Lower Marine Series and the similar horizon of the Upper Marine Series,"‡ while Chamberlin and Salisbury state: "The coal beds that lie between the glacial beds attained the usual thickness."§

It may be well to ask if such facts as the above do not have great bearing on the question of the climate of past coal-forming times. It would appear that a series of comparative studies on peats of tropical and polar climates, with particular attention paid to possible different physical characters of the plants composing them, might give data of importance that would serve as criteria for distinguishing coal of different climates.

A second conclusion that has been reached is that deposits of coal of continental origin may have many of the characters of marine deposits and that in interpretations of the origin of a coal bed, the absence of a fire-clay substratum, the presence of marine fossils, and great uprooting of trees are not necessarily conclusive evidence of marine origin nor even determining evidence against a continental origin by growth *in situ*.

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* Russell, I. C., Bull. Geol. Soc. Amer., p. 99, 1890.

† Plant Geography (Eng. Trans.), pp. 381–382, 1898.

‡ Quart. Jour. Geol. Soc., London, p. 289, 1896.

§ Geology, 2d ed., vol. ii, p. 605, 1907.

Art. VI.—*Hydrolysis of Esters of Halogen Substituted Acids;* by W. A. Drushel and J. W. Hill.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxii.]

1. Acetic Esters.

A great deal of attention has been given by chemists in recent years to the study of the velocity of hydrolysis of esters. Among others, acetic esters have been hydrolyzed under various conditions and the velocity of this reaction measured. In 1883 W. Ostwald* published the results of his experiments in determining the strength of different acids as shown by their catalytic action on the hydrolysis of methyl acetate. Later deHemptinne,† working under the direction of Van't Hoff, determined the rate of hydrolysis of a large number of esters, among them methyl, ethyl and propyl acetates. Löwenherz‡ later took up the subject and included in his studies the methyl and ethyl esters of chloracetic acid and the ethyl di- and tri-chloracetates. Since then Price§ has done some work in the same field, adding isobutyl acetate to the list of esters whose rates of hydrolysis have been measured. All of these investigators, with the exception of Ostwald, used hydrochloric acid as a catalyzer to aid the hydrolytic action of water. VanLaar‖ determined the reaction when water alone was present.

The present work was undertaken to extend our knowledge of the effect on the rate of hydrolysis when the various halogens are substituted for hydrogen in the acetyl end of the ester molecule. It has been shown by Stentor,¶ Buchanan,** Kastle and Keiser,†† and others,‡‡ that the halogen substituted acids react with water and their sodium salts with water and sodium hydroxide, with the splitting out of the halogen and substitution of hydroxyl according to the equations:

$$\mathrm{Cl{-}CH_2COOH + HOH = HOCH_2COOH + HCl}$$
$$\mathrm{Cl{-}CH_2COONa + HOH = HOCH_2COONa + HCl.}$$

Apparently no one with the exception of Löwenherz has investigated the behavior of the esters of the halogen substituted acids.

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* J. prakt. Chem. (2), xxviii, 449.

† Zeitschr. phys. Chem., xiii, 561.

‡ Zeitschr. phys. Chem., xv, 397.

§ Abs. Chem. Soc. (Lon.), xi, 528.

‖ Zeitschr. phys. Chem., xiii, 736.

¶ Proc. Chem. Soc., 1909, 236; Trans. Chem. Soc., 1907, 460.

** Ber. Dtsch. Chem. Ges., iv, 340, 1871.

†† Amer. Chem. Journal, xv, 471.

‡‡ Slator, Trans. Chem. Soc., 1904, 85 and 1291; 1905, 481.

In preliminary experiments, which were made to see if there is any splitting out of halogen in the course of the reaction, N/20 solutions of esters in N/20 acid were placed in the thermostat and titrated from time to time with N/10 silver nitrate solution, using an aqueous solution of potassium chromate as an indicator. In the case of the monochlor- and monobromacetic esters no increase in the free halogen acid was observed even after several weeks. The iodo-esters, however, were apparently decomposed with liberation of iodine, but whether through the decomposition of the acid set free by hydrolysis or directly from the ester we have not at the present time determined.* To prevent possible substitution of chlorine for bromine in the monobromacetic esters, hydrobromic acid was used as a catalyzer; as this has almost exactly the same strength as hydrochloric acid† used with the other esters, the difference in catalyzing effect is negligible. The chlorformic esters, which we had intended to include in our investigation, were rapidly decomposed with evolution of CO_2 showing total decomposition according to the following equation:

$$Cl\text{-}COOC_2H_5 + HOH \longrightarrow HCl + CO_2 + C_2H_5OH.$$

Preparation of Esters.—The methyl and ethyl acetates were prepared in part by the method of Phelps‡ and in part by the method of Thomsen.§ The propyl and isobutyl acetates were prepared by acting with acetyl chloride on the corresponding alcohol. This reaction is rapid and practically quantitative. The halogen substituted esters were generally prepared by the action of chloracetyl chloride and bromacetyl bromide on an alcohol. The methyl and ethyl esters of choracetic acid, however, were prepared from chloracetic acid and alcohol by the method of Thomsen. The mixture of esters with the excess of acid and alcohol was neutralized with Na_2CO_3 and diluted by pouring into a large volume of water. The layers formed were separated and the ester was washed with water, dried over $CaCl_2$ and fractionated. The part boiling within 0·1° to 0·3° of the boiling point given in the literature was taken for the experiments.

The halogen substituted acetic esters are pungent compounds. When perfectly pure they are not disagreeable, but after hydrolysis or before purification their vapors are very irritating to the eyes and mucous membrane. As the vapors of the impure ester contain excess of acid and the mixture of acid and alcohol after hydrolysis have the same effect on the eyes, this action is probably due to the presence of the halogen-substituted acetic acid.

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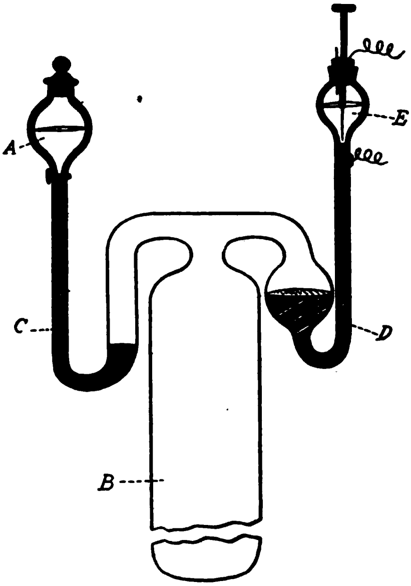
* This point will be investigated by the authors.

† Ostwald, Zeitschr. phys. Chem., iii, 418.

‡ This Journal, xxiii, 368, 1907.

§ Thomsen's Thermochemische Untersuchungen, iv, 201.

The Thermostat.—The thermostat used is cylindrical in form, about 30 inches deep and 33 inches in diameter. It is built of tinned copper and covered with a half-inch layer of felt. It is supported on a heavy iron plate with a twelve-inch hole in the center. This plate rests on legs about eight inches above the floor so that one or more burners may be placed beneath. A coil of lead-pipe around the inner wall about half-way up, conducting steam or cold water, aids in rapidly changing the temperature. For instance, when it is necessary to change from a temperature of 25° to one of 40° this pipe is connected with a steam pipe and steam heat is utilized. On the other hand, a slow stream of cold water enables one to work at a temperature below that of the room. When working at high temperatures the thermostat is covered with asbestos board to prevent radiation of heat from the large surface.



THERMO-REGULATOR.
A and B, toluol; C and D, mercury; E, alcohol.

The thermo-regulator is of special pattern and allows the temperature to be changed at will. This apparatus, shown in the accompanying cut, consists of a vertical cylindrical bulb of 400$^{cm^3}$ capacity filled with toluol. To the top of this bulb two tubes are sealed. These curve downward for about six inches, then upward above the top of the tolnol bulb, the downward portion consisting of 8^{mm} glass tubing and the upward portion of heavy capillary tubing. To the upper end of one of the capillary tubes is sealed a glass-stoppered bulb having a stopcock. A platinum wire is sealed into the other above the level of the water in the thermostat. To the upper end of this capillary tube is sealed an enlarged tube closed with a two-holed rubber stopper carrying an adjustable electrode terminating in a platinum wire. These electrodes are connected with a gas regulator of the Hahn type.* Mercury fills both capillaries and a portion of each of the larger tubes connecting the capillaries with the toluol bulb, the mercury columns being so adjusted that their weights balance each other, thereby preventing leakage of toluol at the stopcock. The tube with the adjustable electrode is filled with alcohol to prevent sparking. When it is desired to change the temperature of the thermostat, all that is necessary to set the thermoregulator is to open the stopcock of the bulb to allow the toluol to pass through and close it again when the proper temperature is reached. The final adjustment is made by raising or lowering the electrode by turning the screw. A Beckmann's thermometer, graduated to 0·01°, is set and clamped in the thermostat to indicate the temperature. Stirring is effected by means of a two-flanged stirrer mounted on ball-bearings and driven by a low speed motor, which is in series with the gas regulator and in parallel with a resistance. Rotary stirring is prevented by a rectangular copper plate fixed near the bottom of the thermostat and so placed as to direct the current upwards. The temperature can be maintained constant within ±0·01° C.

Procedure.—In the case of the esters readily soluble in N/20 acid the amount required to make up a N/20 solution was weighed out in a small flask and dissolved in 250^{cm^3} of the acid used which had previously been warmed in the thermostat to the temperature at which we were working. The mixture was then poured into pressure flasks and these were submerged in the thermostat to within an inch of their mouths. At first Erlenmeyer flasks of about 500^{cm^3} capacity were used, but there was always more or less variation in concentration due to evaporation into the space above the solution and condensation on the colder upper surfaces of the flask. The smaller flasks had less vacant space and being well submerged condensation was prevented to a great extent.

At regular intervals a 25^{cm^3} portion of the reaction mixture was withdrawn with a pipette and run into about 100^{cm^3} of cold distilled water in a 300$^{\text{cm}^3}$ flask. The pipette was allowed to drain 40 seconds and the time at the end of this period was recorded. As soon as possible the mixture was titrated with N/10 $Ba(OH)_2$ with phenolphthalein as an indicator. The end titrations were made on the contents of one of the flasks, usually after the lapse of a week. In the case of the less soluble esters a longer period was necessary before equilibrium was reached. Where N/20 solutions of the esters could not be prepared, saturated solutions were used. These were prepared by adding an excess of ester to the acid solution previously brought to the required temperature in the thermostat. After shaking vigorously for a few seconds the solution was rapidly filtered through a dry filter paper into pressure flasks and placed in the thermostat. This method was adopted to give a homogeneous mixture during hydrolysis.

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* Zeitschr. phys. Chem., xliv, 525.

In Table I are given results of individual experiments. Table II is a summary of the results obtained; the values of K given are averages of values for each experiment. Löwenherz's and deHemptinne's results calculated for 25° and N/20 acid are also found in Table II. Both used the formula $K = \frac{1}{t} \times \log \frac{A}{A - x}$ where t represents time in 5-minute units, A represents initial concentration of the ester and $A - x$ is concentration at the end of $t \times 5$ minutes. Löwenherz worked at 40° and deHemptinne at 25°; both used N/10 hydrochloric acid as a catalyzer. Therefore in calculating the former's results for 25° and N/20 hydrochloric acid, the following formula was used:

$$K = \frac{K \times 2{\cdot}3}{3{\cdot}8 \times 5 \times 2}$$

where K is the velocity constant for 25° and N/20 acid with one-minute time units, 2·3 is the factor to transform to natural logarithms, 3·8 is the coefficient for the temperature change 25° to 40° N/10 acid as found by Löwenherz. Throughout our work the formula $K = \frac{2{\cdot}3}{t} \times \log (T_a - t_o) - \log (T_+ - T_o)$, which is the same formula expressed in terms of titrations, has been used. We have, however, expressed time in one-minute units and multiplied by 2·3 to convert ordinary logarithms to natural logarithms.

Löwenherz found experimentally that the temperature coefficient of N/10 hydrochloric acid for the change from 25° to 40° is 3·8. To obtain this he determined the reaction velocity constant for the same ester at 25° and at 40° and divided the latter by the former. In the same way we determined the coefficient for N/20 hydrochloric acid for the temperature change from 25° to 35° and found it to be 2·0. For N/20 hydrobromic acid it has been found to be 1·7. For the range 25° to 40° hydrochloric has a coefficient of 3·0. These coefficients have been used in calculating some of the results for Table I.

On inspection of this table it will be seen that the rate of hydrolysis is lowered to a marked extent by the introduction of one atom of halogen, the chlorine substituted esters having the lowest rate. The contents of the acetates, chloracetates and bromacetates are to each other as 33 : 21 : 25.

Apparently the most favorable conditions for hydrolysis exist when both base and acid are weak.* In the hydrolysis of the acetic esters we have such conditions, for the alcohols are weak bases and acetic acid is a weak acid, giving a relatively large constant. Chloracetic acid is a stronger acid and the rate of hydrolysis is correspondingly lower. Bromacetic acid is not so strong as chloracetic but much stronger than acetic acid† and its esters are found to have constants slightly larger than those of the chloracetic esters but smaller than those of the acetic esters. The nature of the alcohol seems to have little effect on the rate of hydrolysis.

Table I.

	Methyl Acetate	Methyl Chloracetate	Methyl Bromacetate	
	$10^5 \times K$	$10^5 \times K$	$10^5 \times K$	
	25° and ·05N HCl	25° and ·06N HCl	25° and ·05N HBr	
			I	II
	33·8	25·8	26·4	24·7
	29·5	27·0	26·6	25·3
	33·5	25·2	26·2	24·6
	33·5	27·0	25·5	
	33·2			
	35·0			
Mean	33·0	26·3	26·0	24·8

	Ethyl Acetate		Ethyl Chloracetate	Ethyl Bromacetate	
	I	II		25° and ·05N HBr	
	25° and ·05N HCl	40° and ·123N HCl	25° and ·094N HCl	I	II
	30·1	248·	39·8	24·4	23·6
	28·0	224·	35·0	23·1	24·6
	30·3	272·	36·2	23·8	23·3
	31·5	229·	40·8		
	29·3		38·9		
Mean	29·8	243·	38·9	23·8	23·8

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* Nernst, Theoretical Chemistry, p. 521.

† By inversion of cane sugar Ostwald found acetic acid has value of ·004 and chloracetic acid ·048 that of hydrochloric acid. From determinations of affinity constants he found that chloracetic and bromacetic acids have values near to each other, viz., 0·155 and 0·138. See Jour. prakt. Chem. (2), xxix, 385, 1884. Also Zeitschr. phys. Chem., iii, 418.

	Propyl Acetate		Propyl Chloracetate		Propyl Bromacetate	
	I	II	I	II	I	II
	40° and ·123N HCl	40° and ·08N HCl	25° and ·05N HCl	40° and ·08N HCl	25° and ·05N HBr	40° and ·08N HBr
	220·	201·	20·4	93·0	26·9	134·
	239·	160·	18·6	99·0	26·9	110·
	228·	160·	19·5	92.0	25·3	
			22·9			
–Mean–	229·	173·	20·7	95·0	26·3	122·

	Isobutyl Acetate		Isobutyl Chloracetate		Isobutyl Bromacetate	
	I	II	I	II	I	II
	25° and ·066N HCl	25° and ·066N HCl	25° and ·05N HCl	35° and ·05N HCl	25° and ·05N HBr	35° and ·05N HBr
	44·3	46·7	22·5	43·5	25·4	41·3
	44·8	43·5	20·3	43·5	22·5	40·9
	42·1	43·8	21·4	42·6	26·3	40·3
	45·0	43·4	21·2	41·6	24.0	42·4
	44·4	44·5	21·6	45·1	26·0	40·7
					24·0	40·7
–Mean–	43·5	44·3	21·4	43·3	24·7	41·2

TABLE II.

Mean values of Table I calculated for 25° and N/20 acid.

	Methyl 10^5 K	Ethyl 10^5 K	Propyl 10^5 K	Isobutyl 10^5 K	Mean of series 10^5 K
Acetate	33·2	30·3	31·0	32·8	32·6
	35·0	32·9	34·0	33·4	
	33·3*	33·7*	33·4*		
Monochlor-Acetate	20·1	21·3	20·7	21·4	20·8
	21·8†	19·9†	19·7	21·4	
Monobrom-Acetate	26·0	24·8	26·3	24·7	25·0
	24·8	24·4	25·0	24·7	

* Calculated from deHemptinne's work; Zeitschr. f. phys. Chem., xiii, 561.

† Calculated from Löwenherz's work: Zeitschr. f. phys. Chem., xv, 397.

Summary.

1. The esters of monochlor- and monobromacetic acid show no tendency to decompose with liberation of halogen in aqueous solutions of hydrochloric and hydrobromic acid. Esters of iodine substituted acetic acid in hydriodic acid solution liberate iodine either from the acid set free or from the ester itself.

2. The rate of hydrolysis depending chiefly on the nature of the acid in the ester, is lowered by introduction of halogen in the acid. The acetic, chloracetic, and bromacetic esters of the same alcohol have constants which are in the ratio 33 : 21 : 25. The esters of the different alcohols and any one acid differ but little in the velocity of this acid hydrolysis reaction.*

3. The temperature coefficient for ·05N hydrochloric acid used as a catalyzer for the temperature interval of 25° to 35° is 2·0; for 25° to 40° it is 3·0; for ·05N hydrobromic acid it is 1·7 for the interval of 25° to 35°.

* This has been shown also by the work of Julius Meyer and others, see Zeitschr. phys. Chem., lxvi, 81–125.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A Quantitative Reagent for Iron and Copper.*—In recent years various organic products have come into use as reagents for precipitating metals in quantitative analysis. One of the latest of these is nitroso-phenyl-hydroxylamine, $C_6H_5N(NO)OH$, introduced by Baudisch for the precipitation of ferric iron and copper. The ammonium salt of this base is an article of commerce under the name "Kupferron." Biltz and Hödtke have put the reagent to test and have obtained very satisfactory results. In the precipitation of iron a large amount of acid, either hydrochloric, sulphuric or acetic, may be present; even 20^{cc} of concentrated hydrochloric acid in 100^{cc} of solution does no harm. The reagent was used in 6 per cent solution, being added at room temperature with stirring. The end of the precipitation is readily observed by the formation of a white precipitate of the base itself following the reddish brown iron precipitate. It is recommended to use an excess of about a fifth of the reagent. After 15–20 minutes the precipitate may be filtered on paper, preferably with suction, washed with water at room temperature until the acid is removed, then with strongly ammoniacal water to remove the excess of reagent, and then again with water. The ignition requires some care to prevent loss. Excellent results were obtained in this way in the determination of iron in the presence of aluminium, nickel, and chromium, where in extreme cases as much as 50 parts of each of these metals to 1 part of iron were present. The fact that these separations can be made makes the method a valuable one.

For the determination of copper with this reagent a large excess of mineral acid is to be avoided, and acetic acid appears to be best. Otherwise the operation is the same as for ferric iron, except that the excess of reagent was removed with 1 per cent sodium carbonate solution. Good results were obtained in separating copper from 10 parts of zinc using acetic acid solution, but for the separation of copper from cadmium it was found necessary to use dilute mineral acid solution. Attempts to separate iron and copper by precipitating both together and dissolving out the copper compound on the filter with ammonia gave slightly high results for the iron.

As far as the experiments have gone, it appears that iron and copper cannot be separated from silver, mercury, lead or tin, as these metals are also precipitated.—*Zeitschr. anorg. Chem.*, lxvi, 426. H. L. W.

2. *The Detection and Determination of Very Minute Quantities of Silver.*—The estimation of very small quantities of silver is of importance particularly in connection with atomic weight

determinations, where it is necessary to take into account even the amount of silver chloride dissolved in cold water. G. S. WHITBY of the Royal College of Science, in London, has found a very delicate reaction for this purpose, which consists in adding sodium hydroxide and an organic substance, preferably cane sugar, to the silver solution and heating. He takes 50^{cc} of the liquid, adds a drop of rather strong sugar solution, places the 150^{cc} beaker containing the liquid in a boiling water bath for 2 minutes, then adds 6 drops of a normal solution of sodium hydroxide, and heats for 20 or 30 seconds longer. The yellow color produced, which appears to be due to colloidal silver, is now put into a Nessler tube and compared with colors produced in the same way from known amounts of silver. The colors are accurately proportional to the quantities of silver present, and in this way it is possible to determine 0·000002 g. of the metal in 50^{cc}, or 0·00004 g. in a liter. The author considers the delicacy of the reaction to be about the same as that of the nephelometer method of Richards and Wells, but he thinks that it is more easily and quickly carried out, and involves no complications.—*Zeitschr. anorg. Chem.*, lxvii. H. L. W.

3. *Beryllium Formates.*—It has been found by S. TANTAR that when beryllium carbonate is dissolved in an excess of formic acid the normal formate $Be(CHO_2)_2$ is formed, which is stable upon evaporating the liquid even at a temperature of 100–110° C. This behavior is entirely different from that of the acetate, propionate and isobutterate, which are all basic salts corresponding to the acetate $Be_4O(C_2H_3O_2)_6$, even when anhydrous acids are employed and the evaporation is carried out at a low temperaature, and in order to obtain normal salts of these acids it is necessary to heat the basic salts in sealed tubes with mixtures of the anhydrous acids and their anhydrides. The normal formate, however, is partly hydrolized with the formation of a basic salt upon boiling with water, and when the dry salt is heated under a diminished pressure of $30–35^{mm}$ decomposition takes place and the basic salt $Be_4O(CHO_2)_6$ sublimes. Another organic salt of beryllium is thus added to the list of its remarkable compounds which volatilize without decomposition. This basic salt was prepared in another way, by boiling a solution of the normal formate with the calculated quantity of the carbontate.—*Berichte*, xliii, 1230. H. L. W.

4. *A Recalculation of the Atomic Weights;* by FRANK WIGGLESWORTH CLARKE. 8vo, pp. 548. Washington, 1910. Published by the Smithsonian Institution.

This is the third edition, revised and enlarged, of Dr. Clarke's well-known work, which first appeared in 1882. There is no doubt that the previous editions, in making manifest the imperfections of many of the data, and in pointing out in what direction new work was needed, have had a most important influence upon recent activity in atomic weight research. This recent work has been so extensive and important, particularly that of

Richards and his pupils, that the present edition has been made necessary.

The clear view that this book gives of all atomic weight investigations, and the impression given of the most laborious calculations and the most painstaking conclusions, are its important features. The author has followed his original plan of subjecting all the data, unless they are clearly defective, to a mathematical treatment according to their probable errors. In this treatment most of the older work has practically no influence upon the final results, although in some instances older work seems to have too great an effect upon modern work that is probably freer from constant errors. It is probable that Dr. Clarke's method must be abandoned eventually in favor of using only the most accurate modern results in calculating the atomic weights, but more work appears to be needed before this can be accomplished satisfactorily. In any case the present work is most useful and important. H. L. W.

5. *Pressure of Light on Gases.*—PETER LEBEDEW calls attention to a paper by J. Kepler, "De Cometis Augustæ Vindelicorum, 1619," in which the author comes to the conclusion that the repulsion of comets' tails by the sun is due to a pressure exercised by the light rays. Lebedew also discusses a paper of Fitzgerald, who working on Maxwell's well-known calculation of light pressure, calculated the magnitude of this pressure on the supposition that each gas molecule behaved like an absolutely black sphere under light pressure as black spheres of much larger dimensions. Lebedew quotes recent investigators to show that no restrictions are necessary to the theory that the gas molecule behaves as an absolutely black body, and he proceeds to measure the effect of light pressure, which Kepler was the first to predict—which Maxwell calculated—which Lebedew showed by investigation, and which Arrhenius has made the basis of a wide generalization in cosmical physics. The results of Lebedew's investigation are as follows:

(1.) The existence of the pressure of light on gas is shown experimentally.

(2.) The pressures are directly proportional to the quantity of energy impinging and to the absorption coefficients of the gas.

(3.) Within the faults of observation Fitzgerald's contentions are shown to be true.—*Ann. der Physik*, No. 7, 1910, pp. 411–437. J. T.

6. *Coherers.*—Dr. W. H. ECCLES examines the subject of coherers, mathematically and experimentally, and puts forward the hypothesis that the properties of an oxide coherer "may arise solely from the temperature variations caused in the minute mass of oxide at the contact by the electrical oscillations and by the applied e.m.f.—*Phil. Mag.*, June, 1910, pp. 869–888.

J. T.

7. *Measurement of High Pressure.*—The Reichanstalt at Charlottenburg continues its work on the measurement of pressure by

the change of resistance in manganine wire under pressure. The measurements show that the change is a linear one up to the limit employed, that of 800 k_g/cm^2. Dr. Bridgeman has shown in the Jefferson Physical Laboratory that the change is linear up to 11,000 atmospheres.—*Zeitschrift für Instrumentenkunde*, May, 1910, p. 154. J. T.

8. *Radiochemistry;* by A. T. Cameron. Pp. viii, 174, with 3 portraits and 15 figures. London, 1910 (J. M. Dent & Sons).—The author says in his preface: "The book is intended to be of use to those who, having some knowledge of chemistry and physics, wish to know accurately the facts and theories of the subject at the present time; it is also intended as an introduction for others who wish to master the subject in its entirety."

After having read the book through carefully the reviewer has been unable to avoid the unpleasant conclusion that the author has distinctly failed to attain the ideals set forth in the preceding quotation. A few, typical illustrations may serve to justify this adverse criticism. In the first place, the book contains many errors in physics: On pages 17 and 90 the incorrect formulæ "$I_0/I_t = e^{-\lambda t}$" and "$v_0/v_t = e^{-\lambda t}$" occur respectively. The former equation leads to "$2 = e^{-\lambda t}$," (page 18), which means that a *negative* time is required for the activity to fall to half value. The accepted definition of the direction of an electrical current is violated on page 22. On page 26 the following remarkable sentence may be found: "The secondary rays, occasionally called δ-rays, also travel in straight lines, and otherwise obey the light laws, but are deflected by a magnetic field." On page 94 we read: "Ultraviolet light (*i. e.*, electrons) decomposes water. . . ." On the other hand, the book abounds in infelicities of expression which may be charitably ascribed to careless proof-reading. H. S. U.

9. *Acht Vorlesungungen über Theoretische Physik;* von Dr. Max Planck. Pp. 127. Leipzig, 1910 (S. Hirzel).—These lectures by the distinguished professor of theoretical physics in the University of Berlin were given at Columbia University last year. The first two lectures deal with the fundamental distinction between reversible and irreversible processes, and with the application of thermodynamics to dilute solutions. The third and fourth lectures are devoted to the atomic theory of matter and to the connection between this theory and the empirical principles of thermodynamics. In the two following lectures the theory of "black-body radiation" is developed; this is a subject in which Planck was a pioneer and these two lectures contain a masterly presentation of a very difficult problem and of the progress which has been made toward its solution. In the seventh lecture, the general application of the Principle of Least Action to all reversible phenomena is discussed; and the last lecture contains a very clear and enthusiastic exposition of Einstein's Principle of Relativity. All the lectures are marked by

the lucidity and conciseness which are characteristic of the author. They form an admirable résumé of the present state of theoretical physics and will be read with pleasure and profit by any student of the science. There is perhaps a tendency toward dogmatism in regard to the philosophical interpretation of certain results; but the class of readers to whom the book is addressed will have a sufficiently wide knowledge of the subject to escape the danger of overlooking other points of view.

H. A. B.

10. *The National Physical Laboratory. Report for the Year 1909.* 103 pp., with 2 plates. Teddington, 1910 (W. F. Parrott).—The annual report of the British Standards Laboratory gives evidence of the excellent character of the work which is being done there. The organization of the laboratory embraces five departments: Physics, Engineering, Metallurgy, the Richmond Observatory, and the Eskdalemuir Observatory. Brief reports are given of the work accomplished during 1909 by each department, and of their plans for 1910. An interesting feature is the steady development of international coöperation with the Bureau of Standards and the Geophysical Laboratory at Washington, with the German Reichsanstalt, and other national laboratories.

H. A. B.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey;* GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from xxix, pp. 363–365):

TOPOGRAPHIC ATLAS.—Forty-two sheets.

FOLIOS.—No. 170. Mercersburg–Chambersburg Folio, Pennsylvania; by GEORGE W. STOSE. Pp. 19, with 18 figures, one chart, and 3 colored maps.

No. 173. Laramie–Sherman Folio; by N. H. DARTON, ELIOT BLACKWELDER, and C. E. SIEBENTHAL. Pp. 17, with 7 colored maps and 11 figures.

BULLETINS.—No. 398. Geology and Oil Resources of the Coalinga District, California; by RALPH ARNOLD and ROBERT ANDERSON. With a Report on the Chemical and Physical Properties of the Oils; by IRVING C. ALLEN. Pp. 354, 52 plates, 9 figures.

No. 406. Preliminary Report on the McKittrick–Sunset Oil Region, Kern and San Luis Obispo Counties, California; by RALPH ARNOLD and HARRY R. JOHNSON. Pp. 225, 5 plates, 2 figures.

No. 407. Geology and Ore Deposits of the Bullfrog District, Nevada; by F. L. RANSOME, W. H. EMMONS, and G. H. GARREY. Pp. 130, 14 plates, 20 figures.

No. 415. Coal Fields of Northwestern Colorado and Northeastern Utah; by HOYT S. GALE. Pp. 265, 22 plates, 8 figures.

No. 417. Mineral Resources of the Nabesna–White River District, Alaska; by F. H. MOFFIT and ADOLPH KNOPF. With

A Section on the Quaternary; by S. R. **Capps**. Pp. 64, 5 plates, 3 figures.

No. 419. Analysis of Rocks and Minerals from the Laboratory of the United States Geological Survey, 1880 to 1908; tabulated by F. W. **Clarke**. Pp. xii, 323.

No. 420. Economic Geology of the Feldspar Deposits of the United States; by **Edson** S. **Bastin**. Pp. 85, 4 plates.

No. 422. The Analysis of Silicate and Carbonate Rocks: A Revision of Bulletin 305; by W. F. **Hillebrand**. Pp. 239, 27 figures.

No. 428. The Purchase of Coal by the Government under Specifications, with Analyses of Coal delivered for the Fiscal Year 1908–9; by **George** S. **Pope**. Pp. 80, 8 tables.

No. 430. Advance Chapters from Contributions to Economic Geology—A. Gold and Silver; by J. M. **Hill**, F. L. **Hess**, D. F. **MacDonald** and J. T. **Pardee**—B. Part I. Copper; by L. C. **Graton**, H. S. **Gale**, and G. W. **Stose**. Pp. 66, 5 figures—C. Lead and zinc; by L. J. **Pepperberg**—E. Iron and manganese; by E. C. **Harder**, J. L. **Rich**, A. C. **Spencer**, and **Sidney Paige**. Pp. 56, 1 plate, 4 figures—G. Mineral Paints; by J. C. **Stoddard**, A. C. **Callen**, F. T. **Agthe** and J. L. **Dynan**—I. Salines; by C. L. **Breger** and A. R. **Schultz**.

Water Supply Papers.—No. 236. The Quality of Surface Waters in the United States. Part I.—Analyses of Waters east of the one hundredth meridian; by R. B. **Dole**. Pp. 123.

Nos. 241–249. Surface Water Supply of the United States, 1907–8. Prepared under the direction of M. O. **Leighton**. No. 241. Part I. North Atlantic Coast; by H. K. **Barrows** and R. H. **Bolster**. Pp. 356, 6 plates. No. 243. Part III. Ohio River Basin; by A. H. **Horton**, M. R. **Hall**, and R. H. **Bolster**. Pp. 224, 4 plates, 1 figure. No. 244. Part IV. St. Lawrence River Basin; by H. K. **Barrows**, A. H. **Horton**, and R. H. **Bolster**. Pp. 163, 7 plates, 1 figure. No. 245. Part V. Upper Mississippi River and Hudson Bay Basins; by A. H. **Horton**, E. F. **Chandler**, and R. H. **Bolster**. Pp. 133, 5 plates, 1 figure. No. 247. Part VII. Lower Mississippi Basin; by W. B. **Freeman**, W. A. **Lamb** and R. H. **Bolster**. No. 248. Part VIII. Western Gulf of Mexico; by W. B. **Freeman**, W. A. **Lamb**, and R. H. **Bolster**. Pp. 171, 4 plates, 1 figure. No. 249. Part IX. Colorado River Basin; by W. B. **Freeman** and R. H. **Bolster**. Pp. 206, 10 plates.

2. *Illinois Geological Survey.* Bulletin No. 13, The Mississippi Valley between Savanna and Davenport; by J. **Ernest Carman**. Pp. xi, 85; 23 plates, 26 figures and map. University of Illinois, Urbana, 1909.—This is another of the excellent educational bulletins issued by the Illinois Survey. While the object of the bulletin is to give a detailed account of the stratigraphy, physiography and glacial geology of this part of the Mississippi Valley, it should attract readers beyond the state because of the clear way in which the accepted views regarding glaciation, and particularly eolian sand and loess, are discussed.

Bulletin No. 14, Year-Book for 1908; H. Foster Bain, Director. Pp. viii, 386, 5 plates, 5 figures.—The Illinois Survey continues to do a large amount of effective work as indicated by its publications and its plans for the future. Its organization, including the geological section, topographic section, and drainage section, is admirably designed to meet the particular needs of the state. Furthermore, desire to prevent duplication of work is indicated by the fact that the Survey is in active coöperation with the United States Geological Survey, United States Department of Agriculture, the State Water Survey, the Internal Improvement Commission, the State Conservation Commission, as well as with the University of Illinois and Augustana College. The request for an increase in the annual appropriation from $25,000 to $35,000 is certainly justified by the work accomplished.

The important classes of work undertaken by the Geological Section are: The study of drill records in connection with stratigraphic work under the direction of Weller, Savage and others, with a view to ultimately making a structural map of the state; a study of the coal fields preliminary to detailed mapping; investigation of Portland cement material including clays and shales. The fact that Illinois ranks second in coal production explains the need for stratigraphic and structural work; and the large importation of Portland cement justifies care in investigating local resources.

The Topographic Section in coöperation with the Geological Survey has mapped 4366 square miles, leaving, however, a large part of the state, 47,847 square miles, still to be covered. The Drainage Section is devoting its attention chiefly to an examination of "bottom lands" because at the present time 90 per cent of these lands are unprotected from floods, and it is estimated that $100,000,000 would be added to farm values of the state if these lands could be reclaimed. Seven special reports are included in this bulletin. H. E. G.

3. *Northern Territory of South Australia: North and Eastern Coasts. Report of Geological Reconnaissance from Van Dieman Gulf to the McArthur River, etc., made by the Government Geologist in 1907;* by H. Y. L. Brown. Government Geologist. Pp. 12, with map. Adelaide, 1909.—Continuing the exploration carried on during 1905, Mr. Brown explored in a preliminary way the region along the North Australian Coast line from Van Dieman Gulf to Melville Bay. This region is practically unknown scientifically, a fact which justifies the inclusion of notes regarding the condition of the natives, the character of the coast line, the fauna, flora and climate of the region as well as the geology. In this reconnaissance trip no detailed geological work was done, but the presence of the pre-Cambrian, Cambrian, Permo-Carboniferous, Cretaceous, and Tertiary sediments are proven, as well as the presence of basalt, and certain other types of volcanic rock. Valuable gold deposits were found, the presence of tin and bauxite in commercial quantities was demonstrated, and the boring for coal at Mallison Island, Arnheim Bay, and Boroloola is recommended.

It is to be hoped that the reconnaissance survey is to be followed by detailed work, which will result in a fuller knowledge of this interesting and unknown region. H. E. G.

4. *Corrasion by Gravity Streams with Applications of the Ice Flood Hypothesis;* by E. C. ANDREWS, Department of Mines, Sydney. Reprinted from Journal and Proc. of the Royal Society of N. S. Wales, vol. xliii, pp. 204–330, with 11 figs., 3 appendices and a bibliography.—This is an important paper which should be called to the attention of American geologists interested in surface processes. The author is best known by his previous paper on the Ice Flood Hypothesis,* in which he maintained the excessive erosive power of glaciers during their period of maximum development, or flood, as compared with their weak erosive effects during stages of recession. In the present paper he takes up the subject of stream erosion more broadly as the action of the gravity stream, irrespective of the fluid or solid which composes it, and discusses the laws of its movement. To sum up the results of his conclusions it may be noted,—that U-shaped valleys and cirques are forms characteristic of maximum or flood erosion and are not forms solely dependent upon ice as a medium. Even where the stream of ice or water covers a region broadly it will erode unequally. During the flood stages it shows an excessive effect upon the bottoms of the principal channels in contrast to its flood plain and increases the relief of the region. During drought stages aggradation tends to take place within these overdeepened and oversteepened channel walls. Through the formulation of these principles the author discusses changes in the character of glacial erosion between the ice age and the present, and draws distinctions between those features which are essentially peculiar to ice as a medium. Applications of his discussions resulting in some new conclusions are made, among other regions, to the California Sierras, the Finger Lake region, the St. Lawrence and the Hudson Rivers.

As the original paper may be difficult of access to many who may wish to quote some of Andrews' statements, the following conclusions are quoted, the bearing of which may be better appreciated in the light of the preceding statements:

"A. *Inductive Studies.*—(1) Cirques, hanging valleys, rock basins, facetted spurs (or spurless walls), smoothed cols, "steps," and "treads" occur in all recently glaciated regions. (2) In proportion to the intensity of the recent glaciation so are these peculiar land profiles pronounced in number, size, and appearance. (3) In localities not glaciated recently such peculiar land profiles are absent. (4) All these forms are matched in miniature along any channel determined by thunderstorm waters. (5) Along the beds of even large stream channels similar forms occur to those just enumerated. (6) The forms in all these cases are similarly situated with respect to their enveloping channels. (7) The forms in each case are adjusted to the size of the various stream volumes (whether ice or water) known to have been associated with them.

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* Jour. Geol., vol. xiv, pp. 22–54, 1906.

"B. *Inductive Studies.*—(1) All streams in nature are due primarily to pressure and weight. (2) The path of any stream particle tends to the parabolic form. (3) All must seek the lines of least resistance, and inasmuch as a vertical force (gravity) determines the flow, the lines of least resistance will be the lines of quickest descent for streams. (4) All streams therefore tend to fellow the thalwegs of each other as opportunity arises. (5) Increased pressure as weight implies the increased mobility or velocity of a stream. (6) Increased velocity implies corrasive action rising in a high geometrical ratio. (7) From the foregoing the profiles of all stream channels formed individually by one stream type only should therefore be similar in general appearance. (8) The forms developed by the general stream have been worked out by means of these principles. (9) But the forms deduced for the general stream are matched in nature in the case of the ordinary water stream (which has been definitely observed moreover to have formed its own channel profiles). (10) Therefore any group of such similarly shaped, similarly situated, and similarly associated profiles as those deduced for the general stream can be satisfactorily explained by stream action. (11) But such groups of forms occur in regions of recent glaciation. (12) They can be satisfactorily explained, therefore, by stream action. (13) Moreover, glaciers themselves are streams. (14) Glaciers in recent times occupied the same general relations (as to size, surface, and so on) to cirques, lake basins, over-deepened valleys, and other associated forms which the general stream type has been deduced to occupy with regard to its own channel forms. (15) With the exception of a glacier no other stream in these glaciated regions is known which had the power to fashion the typical cirque, rock basin and spur "facet." (16) Glaciers therefore, in all probability, formed the typical cirques, the fiord and Alpine basins, the spurless chasms of Alpine regions, as also the hanging valleys and the "steps" and "treads" in Alpine valleys.

"C. *Apparent Lack of Ice Corrasion as Evidenced by a Study of Present Glaciers.*—The channel form is adjusted to the strength of the stream. Upon a reduction of stream volume a readjustment of the channel grade is set up, and the stream appears most inert at the locations of the maximum energy exerted by the larger stream. This is the case with present-day glaciers. The recent ice-floods formed cirques, rock basins, and other forms adjusted to their own size and strength, while the deglaciated valleys of to-day evidence the very recent retreat of the last ice flood. The channel grade, therefore, must now be readjusted. This being so, morainic material must fall out along the old cutting curves, and the ice generally must be most inert at spots like fiords and lake basins. This explains the apparent anomaly otherwise of the association of inert and banded glaciers with cirques and rock basins, and the occupation of old ice-cutting curves by moraines." H. E. G. J. B.

5. *Die Antike Tierwelt;* by **Otto Keller.** Erster Band. Säugetiere I. Pp. xii, 434, with 145 text-figures and 3 plates. Leipzig, 1909 (Wm. Engelmann).—This very interesting volume describes, with many illustrations, the various mammals known to the ancients, not only the domesticated animals but wild and some mythical forms as well: more than 200 species and varieties all told, such as are depicted in statuary, bas reliefs, mural paintings, coins and vases, or described by the writers of old.

The volume opens with a brief résumé of the zoölogical system of Aristotle, the remainder of the book being devoted to the Mammalia, of which the principal forms described are the apes, the lion and other felines, the dog, hyena, bear, many rodents, among which are mentioned the conies (*Hyrax*), which are nearer the proboscideans among the ungulates than the hares which they superficially resemble. Horses, deer, giraffe, antelope, and their kind were well known to the ancients, and the elephants, including the hairy mammoth, which is depicted in prehistoric drawings upon cavern walls of France. Rhinoceros, swine, seals, and an amazing picture of a docile unicorn from the mediæval "Physiologius" close the volume. There are three plates of coins and medals bearing animal subjects.

The book, with its excellent illustrations and clear type, is of great interest and value to the natural historian as well as to the general reader. R. S. L.

6. *The Orders of Mammals;* by **William K. Gregory.** Bulletin of the American Museum of Natural History, Vol. xxvii, Feb. 1910, pp. 1–525, and 32 text-figures.—Part I of this important memoir contains a history of the ordinal classification of mammals, while Part II deals with the genetic relations of the mammalian orders, a discussion of the origin of the Mammalia, and the problem of the auditory ossicles. Dr. Gregory's position in the American Museum which calls for so much literary as well as scientific research, together with close association with Professor Osborn and Dr. W. D. Matthew, have aided in fitting him peculiarly for the preparation of such a work. The author's thoroughness may readily be imagined by his devoting some time to a preliminary study of Descartes and the principles of inductive philosophy in order that his phylogenetic speculation be not rendered migratory by faulty reasoning.

This thoroughness is the keynote of the whole endeavor and has resulted in so valuable a work that a teacher of paleontology as well as one who deals with living mammals will find it a mine of information above price. It is written in the author's clear and very delightful style, while the typography is fully up to the high standard of the Museum's other publications. R. S. L.

7. *Analyse der Silikat- und Karbonatgesteine;* von **W. F. Hillebrand.** 8vo, pp. 258. Leipzig 1910 (W. Engelmann).—This is essentially a translation into German, by **E. Wilke-Dörfurt**, of Bulletin No. 305 of the U. S. Geological Survey (1907) by the same author.* At the same time, however, con-

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* A revised edition has recently appeared as Bulletin 422, see p. 84.

siderable alterations and additions to the text of the original volume have been made by the author, which embody the results of more recent researches on methods of analytical work. They relate chiefly to the preparation of samples for analysis and to the estimation of water and the oxides of iron.

The writer in his preface to the German edition pays a graceful tribute to the German masters, especially Bunsen, under whom he studied, and this volume will be evidence to the chemists of that nationality that the seed sowed at that time has brought a fruitful harvest. There is no one who has greater skill, or has had a wider experience, in silicate analysis than the author, or who has done more to bring the analyses of rocks to a high standard, and it is well that his views and methods should have as wide an extension as possible. L. V. P.

8. *Manual of the Chemical Analysis of Rocks;* by H. S. WASHINGTON. Second edition, Revised and Enlarged. 8vo, pp. 200. New York, 1910 (Wiley & Sons).—This is a new edition of Washington's useful and practical treatise on rock analysis. New methods and modes of procedure, which have been tested by the author, have been introduced and numerous changes have been made in the text where more detail appeared to be needed. The analysis of carbonate rocks, as a special subject, has not been treated, as the latest work of Dr. Hillebrand, recently noticed in this Journal, covers this, and they are of minor importance to the petrographer.

The complete and accurate analysis of silicate rocks is one of the most intricate and difficult tasks the analytical chemist is called upon to perform, but by the aid of this work, in which every detail of operation is completely stated, even one of limited experience in this field may attain excellent results if he carefully follows its directions. It may be confidently recommended to chemists and petrographers, and should find a place in every chemical library. L. V. P.

9. *Handbuch der Minerologie;* von DR. CARL HINTZE. Erster Band. Dreizehnte Lieferung. Pp. 1921–2080. Leipzig, 1910 (Veit & Comp.).—The successive parts of Hintze's monumental work on Mineralogy do not appear at very frequent intervals, but are none the less welcome on that account. This is the twenty-fifth section of the entire work and the thirteenth of the first volume; it is devoted to the oxides and chiefly to the species of the diaspore-goethite group.

10. *Crystallography: An Elementary Manual for the Laboratory;* by M. EDWARD WADSWORTH. Pp. xvi (20), 299, with 612 figures, and 25 plates. Philadelphia (John Joseph McVey), 1909.—This new Crystallography is based on the lectures delivered by the author at Harvard in 1873 and subsequently developed by him in University work elsewhere. Being prepared for those studying the subject in a general way only, the mathematical side is omitted entirely, and the discussion is limited to simple and readable descriptions of the different systems and the forms

peculiar to them, with a statement of the different types of symbols in use. The work differs from most books of similar scope in that the triclinic system is introduced first, a method which the author has found to give the best results with his pupils. The figures are numerous and are all presented in a series of twenty-five plates printed on thin paper and placed at the end of the volume.

11. *Brief Notices of some recently described Minerals.*—**Anophorite** is an alkaline amphibole described by W. Freudenberg as occurring in the shonkinite of Katzenbuckel, Baden. It has the pleochroism of Brögger's cataphorite, but differs in chemical composition and in optical orientation; specific gravity, 3·166. Analysis gave:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	
49·79	5·37	1·98	7·54	9·18	0·36	11·59	3·16	7·92	1·85	1·52	= 100·26

—Ref. in *Jahrb. Min.*, i, 34, 1910.

Bityite is a hydrated silicate of calcium and aluminium described by A. Lacroix from the pegmatite veins of Mt. Bity, Maharitra, Madagascar. It occurs in minute hexagonal (pseudohexagonal) plates of a yellowish-white color; hardness, 5·5; specific gravity, 3·05. An analysis by Pisani gave:

SiO_2	Al_2O_3	CaO	BeO	MgO	Li_2O	Na_2O	K_2O	H_2O	
31·95	41·75	14·30	2·27	0·13	2·73	0·40	0·16	6·50	=100·19

—*Bull. Soc. Min.*, xxxi, 241, 1908.

Brugnatellite is a hydrate and carbonate of ferric iron and magnesium, described by E. Artini, from Val Malenco, where it occurs in a serpentized peridotite. It forms lamellar aggregates of micaceous aspect, easy cleavage, pearly luster and flesh-red color. An analysis gave:

CO_2	Fe_2O_3	MgO	MnO	H_2O	insol.	
7·78	13·20	42·79	1·80	33·77	1·03	= 100·37

From this the formula is calculated:

$$MgCO_3.5Mg(OH)_2.Fe(OH)_3.4H_2O.$$

Named after Professor L. Brugnatelli of Pavia.—*Rivista Min. Ital.*, xxxvii, 119, 1909.

Hallerite is a silver-white mica with pearly luster described by Ph. Barbier, from the pegmatite of Mesvres, Autunois. It is near paragonite, yielding 7·63 p.c. Na_2O and 1·26 Li_2O. Named after Professor Haller of Paris.—*C. R.*, cxlvi, 1220, 1908.

Joaquinite is a rare titano-silicate of calcium and iron described by G. D. Louderback in a recent pamphlet which gives an exhaustive account of the remarkable barium titano-silicate benitoite. It occurs in small, honey-yellow or light brown crystals, enclosed in both natrolite and neptunite; the crystals are imperfect in form, but are referred with probability to the orthorhombic system. Its hardness is 5·5–6, specific gravity, 3·85–3·9, and refractive index high, greater than 1·73. Only qualitative tests have thus far been made, but it is hoped that material for a complete analysis may be obtained.—*Bull. Geol. Univ. California*, v, p. 331.

Plancheite is a hydrated copper silicate described by Lacroix from Mindouli, French Congo. It occurs in fibrous masses of a blue color associated with dioptase; specific gravity, 3·36. An analysis by Pisani gave:

SiO_2 37·16 CuO 59·20 FeO *tr.* H_2O 4·50 = 100·86.

Named after M. Planché.—*Bull. Soc. Min.*, xxxi, 250, 1908.

Risörite is a niobate of the yttrium and cerium metals with other elements; it is described by O. Hauser from the pegmatite of Risör in southern Norway. It has a brown color, and is optically isotropic, probably from alteration; hardness, 5·5; specific gravity, 4·179; after ignition, 4·678. It is not far from fergusonite, but contains uranium in very small amount only.—Ref. in *Jahrb. Min.*, i, 37, 1910.

Rosasite is a carbonate of copper and zinc, described by D. Lovisato from the Rosas mine, Sulcis, Sardinia. It occurs in mammillary masses with fibrous structure and green to sky-blue color; hardness, 4·5, specific gravity, 4·07. Analysis gave:

CO_2	CuO	ZnO	PbO	H_2O
30·44	36·34	33·57	*tr.*	0·21 = 100·56

—*Rend. Acc. Linc.*, xvii (2), 723, 1908.

Vashegyite is a basic aluminium phosphate described by Zimanyi, from the iron mines of Vashegy, Hungary. It occurs in dense white masses resembling meerschaum and immediately associated with variscite; hardness, 2·5. An analysis by Loczka gave:

P_2O_5	Al_2O_3	Fe_2O_3	H_2O	K_2O	Na_2O	CO_2	insol.
31·32	28·33	1·19	38·97	0·16	0·05	0·12	0·24 = 100·38

The calculated formula is $4Al_2O_3.3P_2O_5.30H_2O$.—*Zeitschr. Kryst.*, xlvii, 53, 1909.

Samsonite is a sulphantimonite of silver and manganese from the Samson vein of the St. Andreasberg silver mines in the Harz; it is described by Werner and Fraatz. It occurs in monoclinic crystals, the color is red by transmitted light and it somewhat resembles miargyrite. An analysis, after deducting unessential constituents, gave:

S 20·45 Sb 26·33 Ag 45·95 Mn 5·86 = 98·59

This leads to the formula $2Ag_2S.MnS.Sb_2S_3$.— *Centralblatt Min.*, p. 331, 1910.

12. *Les Cristallisations des Grottes de Belgique*; par W. Prinz. Pp. 90, with 143 figures. Brussels, 1908.—The stalactitic formations in limestone caverns have often been described, but never

before with the fullness and care devoted to them in the present work. The author has had the opportunity to study the numerous caves in Belgium which afford stalactites and stalagmites of very great variety. Many of these are distinctly crystallized and show different rhombohedrons and scalenohedrons which can be definitely determined. In addition to the distinctly crystallized forms are many others of much interest and variety.

13. *Minéralogie de la France et de ses Colonies;* by A. LACROIX. Tome Troisième, 2e Partie. Pp. 401–815. Paris (Librairie Polytechnique, Ch. Béranger, Editeur), 1909.—The earlier parts of this admirable Mineralogy of France and the French Colonies have been repeatedly noticed in this Journal. The present part completes Volume III and thus the entire work. It is devoted for the most part to the carbonates, and the species calcite, aragonite, and cerussite are discussed with admirable fullness, the text being accompanied by numerous illustrations. The author is to be congratulated on having brought to completion a work of such magnitude and importance.

III. NATURAL HISTORY.

1. *Fungous Diseases of Plants with Chapters on Physiology, Culture Methods and Technique;* by BENJAMIN MINGE DUGGAR, Pp. xii, 508, 240 figures. Boston and New York (Ginn and Company), 1909.—The writer was recently informed by an experienced mycologist of Europe that the United States led the world in the study of plant diseases, especially as regards their treatment. It is certainly true that since the establishment of the experiment stations in this country the study of fungous diseases has occupied a very prominent part in the work of the various station botanists. Until recently, however, we have had no text-book from an American author upon this very important branch of botany, though the subject is now taught either specifically or in a general way in most of our colleges.

Professor Duggar of Cornell University has the honor of giving us this first text-book, the title of which is quoted above. While the book is apparently designed primarily as a text- or reference-book for college use, it is of value to anyone wishing a general up-to-date knowledge of the subject. It is divided into three parts, of which the first and second treat of culture methods, technique and physiological relations of the fungi. The greater part of the volume, however, is occupied by the third part, with descriptions of the most important fungous diseases of our economic plants. These fungi are taken up according to their systematic relationships, and under each is given its more important literature, its general life history, and the methods employed in controlling it.

The book is well illustrated with halftones and drawings. The text is carefully written and the mechanical execution is above the average. On the whole, it is a work that fills a decided need, and the subject is presented in a manner very creditable to the author. G. P. C.

2. *The British Freshwater Rhizopoda and Heliozoa;* by the late JAMES CASH, assisted by JOHN HOPKINSON. Volume II, Rhizopoda, Part II. Pp. xviii, 166, with 16 plates, of which 10 are colored. London (Ray Society). 1909.—This is the second of the three volumes of the Monograph on these widely distributed groups of Protozoa, the first volume, including the Amœbina and a part of the Arcellida, having been published in 1905, while the third volume is promised for an early date. Of the Conchulina, or case-bearing Rhizopods, the present volume describes some 80 species belonging to 14 genera, all of which are illustrated. As many of the species occur not only in Great Britain, but also in America and other parts of the world, the book will have a wide sphere of usefulness. For students of North American zoology it will form a valuable supplement to Leidy's superbly illustrated Monograph on the North American Freshwater Rhizopods, published some thirty years ago by the U. S. Geological Survey of the Territories. W. R. C.

3. *Guide to the Genera and Classification of the North American Orthoptera;* by SAMUEL HUBBARD SCUDDER. Pp. 89. Cambridge, 1897 (Edward W. Wheeler).—A key for the use of entomologists, with bibliographical notes to date of publication. W. R. C.

4. *Nature Study by Grades: A Text-book for Lower Grammer Grades;* by HORACE H. CUMMINGS. Pp. viii, 208. New York, 1910 (American Book Company).—This attractive little book consists of topics for two years' work in nature study, adapted to children of ten or twelve years of age. The subject is divided into 120 lessons, each of which furnishes suggestions which should encourage the pupil to observe the familiar phenomena of nature and the properties of the common things about him. W. R. C.

5. *The Body and its Defences;* by FRANCES GULICK JEWETT. Pp. viii, 342, illustrated. Boston and New York, 1910 (Ginn and Company).—Essentially a practical discussion in simple language of the natural conditions which prevail in the human body, to the end that the reader may clearly understand the baneful effects of unhygienic living. The penalties which may thus result from ignorance or disregard of the proper care of the bodily mechanism are vividly illustrated, and practical advice is given as to how, by coöperation with the natural defences of the body, such penalties may be largely avoided.

This book carries a message that should impress the reader, be he schoolboy or adult, with a higher sense of his responsibility for the welfare of his own body. W. R. C.

6. *A Synonymic Catalogue of Orthoptera;* by W. F. KIRBY. Vol. III, Orthoptera Saltatoria. Part II (Locustidæ vel Acridiidæ). Pp. vii, 674. London, 1910 (printed by order of the

Trustees of the British Museum: sold by Longmans & Co. and others).—This third volume of the catalogue of the Orthoptera in the British Museum completes the work undertaken by Mr. Kirby a number of years since. It is devoted to the Locustidæ or Acridiidæ, that is, the short-horned grasshoppers or migratory locusts. Volume I of the catalogue was issued in 1904, Volume II in 1906. An Appendix and Catalogue bringing it up to date was at one time contemplated but found to be impracticable.

7. *Catalogue of British Hymenoptera of the Family Chalcididæ;* by CLAUDE MORLEY. Pp. 28. London, 1910 (printed by order of the Trustees of the British Museum), sold by Longmans & Co., and others, 1910.—A catalogue has now been issued of the difficult and little-known group of the Calcididæ, about which practically nothing has been published since the time of Francis Walker. With this work the series of catalogues of British Hymenoptera is now complete.

8. *Catalogue of the Lepidoptera Phalænæ in the British Museum.* Volume IX. *Catalogue of the Noctuidæ;* by Sir GEORGE F. HAMPSON. Pp. xv, 552, with 11 plates and 247 figures. London, 1910.—This ninth volume of the Catalogue of Moths represented in the British Museum includes the third and final portion of the large Noctuid sub-family Acronyctinæ It contains 725 species belonging to 185 genera.

9. *The Museum of the Brooklyn Institute of Arts and Sciences.*—The following has recently appeared: Science Bulletin, Vol. I, No. 17. Additions to the Carabidæ of North America with Notes on Species already known; by CHARLES SCHAEFFER. Pp. 391–405. May, 1910.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Carnegie Foundation for the Advancement of Teaching.* Bulletin No. 4. Medical Education in the United States and Canada: A Report to the Carnegie Foundation for the Advancement of Teaching; by ABRAHAM FLEXNER; with an Introduction by HENRY S. PRITCHETT. Pp. xvii, 346. New York, 1910.—The management of the Carnegie Foundation has taken a broad view of the work which has devolved upon it. What it is doing in the general line of University and College work is well known, but in this bulletin we have the first of a series of papers devoted to the Professional Schools. This has been prepared by Mr. Abraham Flexner; he deals with the whole subject of medical education, treating it not only historically but taking up what is regarded as the proper basis of a medical education as compared with that actually existing, and dealing also with other topics, such as laboratories, the relations of the hospital and the medical school, etc. The latter half of the work gives the data collected in regard to the individual schools in the United States and Canada, arranged alphabetically. The standard called for is cer-

tainly high—much higher than that to which the majority of medical institutions now attain—but not too high to insure the best possible training of medical men for the sake of the public to whom they are to minister.

2. *Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are noted in the following list (continued from p. 368, v. xxix).

No. 85 (Delaware). Index of Economic Material in Documents of the States of the United States. Delaware 1789–1904. Prepared for the Department of Economics and Sociology of the Carnegie Institution of Washington ; by **ADELAIDE R. HASSE.** Pp. 137, 4to.

No. 87, Volume II. The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission. In two volumes and Atlas. Volume II : The Mechanics of the Earthquake; by **HARRY FIELDING REID.** Pp. viii, 192, 4to, with 2 plates and 62 figures.

No. 96 (Part 2). Condensation of Vapor as induced by Nuclei and Ions. Fourth Report ; by **CARL BARUS.** Pp. viii, 84.

No. 105. Factor Table for the first Ten Millions, containing the Smallest Factor of Every Number not divisible by 2, 3, 5, or 7 between the limits 0 and 10017000 ; by **DERRICK NORMAN LEHMER.** Pp. 476, folio.

No. 115. Preliminary General Catalogue of 6188 Stars for the Epoch 1900, including those visible to the naked eye, and other well-determined stars; prepared at the Dudley Observatory, Albany, New York, by **LEWIS BOSS.** Pp. xxxvii, 345, 4to, with 3 appendices.

No. 123. Respiration Calorimeters for Studying the Respiratory Exchange and Energy Transformations of Man; by **FRANCIS G. BENEDICT** and **THORNE M. CARPENTER.** Pp. vi, 102, with 32 figures.

No. 125. Determination of Atomic Weights. Further Investigation concerning the Atomic Weights of Silver, Lithium, and Chlorine ; by **THEODORE W. RICHARDS** and **HOBART HURD WILLARD.** The Harvard Determinations of Atomic Weights between 1870 and 1910 ; by **THEODORE W. RICHARDS.** Methods Used in Precise Chemical Investigation; by **THEODORE W. RICHARDS.** Pp. iv, 113.

3. *Publications of the Allegheny Observatory of the University of Pittsburgh.*—The following paper has recently appeared: Volume I, No. 22. The Spectroscopic Binary β Aurigæ ; by **ROBERT H. BAKER.** Pp. 163–190, with 14 tables.

OBITUARY.

WILLIAM PHIPPS BLAKE, Professor of Geology, emeritus, in the University of Arizona, died on May 22d at Berkeley, California, whither he had gone to take part in the fiftieth anniversary of the University of California. He was born in New

York on June 1st, 1826, and was educated at the Scientific School of Yale University in 1852, being one of three to receive the degree of Ph.B. in the first class of the institution; his colleagues were Professors Brush and Brewer of New Haven.

The career of Professor Blake was interesting and varied, especially in the exploration of wild regions which have now become comparatively well-known. From 1854 to 1856 he acted as mineralogist and geologist in the explorations and surveys for the proposed Pacific railroad, reaching California by the southern route only a few years after the discovery of gold, when the excitement was still at its height. At that time he first called attention to the great Colorado desert with its extensive area below the sea-level. He also carried on mining explorations in North Carolina and Georgia in 1860, and from 1861 to 1863, with Mr. Raphael Pumpelly, was employed by the Japanese Government in the examination of the mineral resources of that country. Before returning from Japan he visited China and also Alaska, where he explored the Stickeen River and its glaciers. This was shortly before Alaska was purchased by the United States Government in 1867. In 1863 he visited California again, and was engaged as mining expert in connection with the Comstock lode. His varied work in similar lines was further extended by a trip to Santo Domingo in 1871. In another direction also he served his country and science well and had wide experience of a different kind, being Commissioner to the World's Fair of 1853, as also at the subsequent World's Fairs of Vienna in 1873, Philadelphia in 1876—the Centennial Exposition—and Paris in 1878. In 1864 he was Professor for a time in the College of California, later the University of California, and thirty years afterwards he became Professor of Geology and Director of the School of Mines of the University of Arizona; he was also territorial geologist of Arizona for many years. In 1895 he became Professor emeritus; his death came suddenly from pneumonia when he lacked but a few days of completing his 84th year.

Dr. **George Frederick Barker**, Professor of Chemistry, emeritus, at the University of Pennsylvania and for many years an associate editor of this Journal, died on May 24 at the age of seventy-five years. A notice is deferred till a later number.

Professor **Franklin C. Robinson**, the chemist, long connected with Bowdoin College, died on May 25 at the age of fifty-eight years.

August von Mickwitz, the well-known City Engineer and Paleontologist of Reval, Russia, died on April 20th last at the age of 61 years. His best known work in paleontology treats of the Upper Cambrian Obolidæ and Lingulidæ of western Russia.

Robert H. Gordon, long interested in the geology of western Maryland, and the donor of extensive collections of the finely preserved Lower Devonian fossils of this region to the U. S. National Museum and to Yale University, died on May 10th last at the age of 58 years.

New Circulars.

84: Eighth Mineral List: A descriptive list of new arrivals, rare and showy minerals.

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rof. W. G. Farlow.

VOL. XXX. AUGUST, 1910.

Established by **BENJAMIN SILLIMAN** in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

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FOURTH SERIES

VOL. XXX—[WHOLE NUMBER, CLXXX.]

No. 176—AUGUST, 1910.

WITH PLATE I.

NEW HAVEN, CONNECTICUT.

1910.

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URAL MOUNTAINS.

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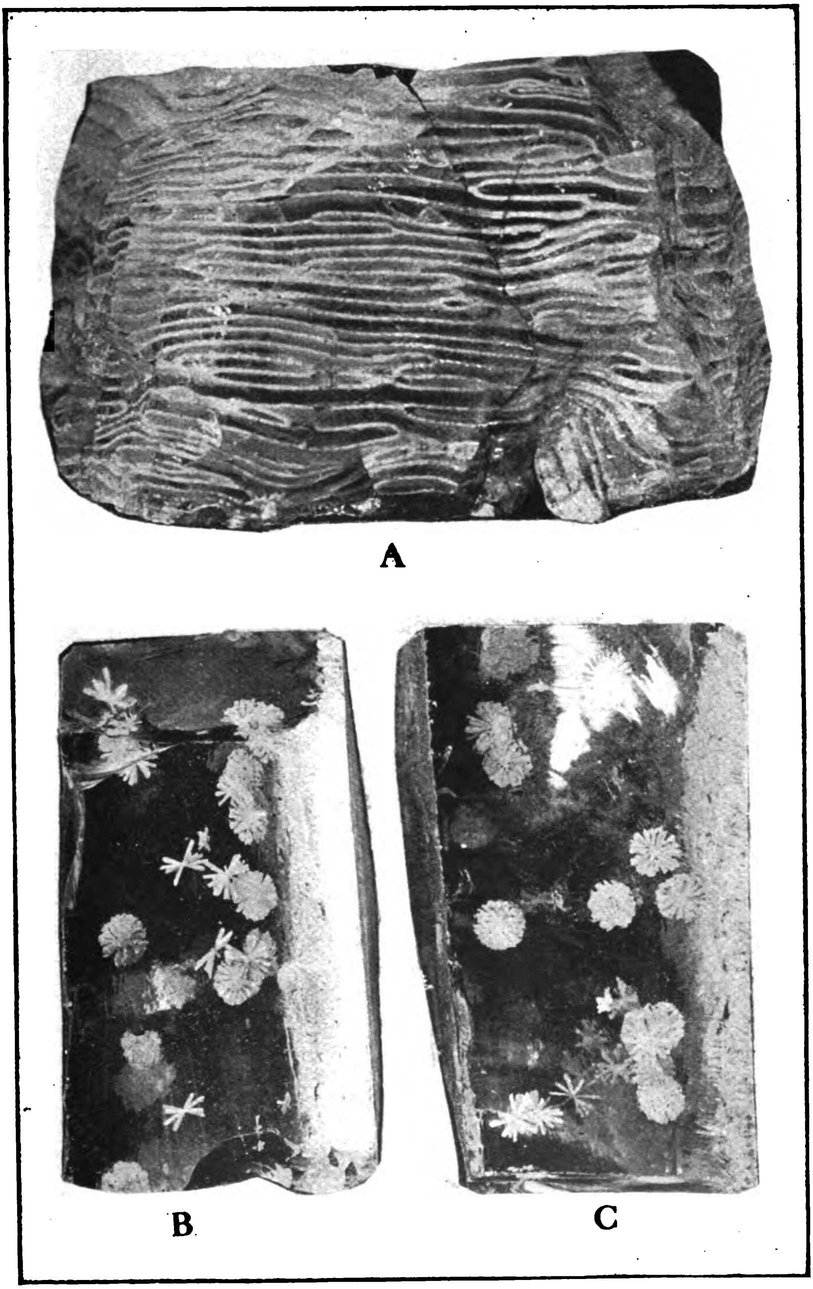

Spherulites in Artificial Glass.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VII.—*On an Artificial Lava-Flow and its Spherulitic Crystallization;* by L. V. PIRSSON. (With Plate I.)

THE material which forms the basis of the following article, was obtained a number of years ago by the late Prof. Chas. E. Beecher, of Yale University, at Kane, an industrial town with glass-works, in McKean county, Penn., and presented to the writer. It appears that one of the furnaces in the glass-works accidentally broke, allowing the molten glass to escape; it flowed into the pit below and cooled there. When cold the mass of glass was blasted out and the broken material piled on one side. It was from this broken material that the specimens were obtained. The furnace is stated to have been 60 feet long by 25 feet wide, and the molten glass in it at the time to have been from 4 to 5 feet deep. This would have made about 6000 cubic feet of glass, or say 700,000 pounds, an amount which formed a flow of no mean size, when viewed from the experimental standpoint. During the flow and while cooling it partially crystallized, assuming features which it is the object of this paper to present. An accident of this kind to a glass furnace by which a flow of molten glass was produced, which partly crystallized, has been described by the late Professor Fouqué.* In this case portions of the glass were filled with milky white nodules with a greenish cast of color, which were in places the size of a nut. These nodules were spherulites which Fouqué proved to consist of radially fibrous prisms of wollastonite. Thanks to the kindness of Professor A. Lacroix of the Musée d'histoire naturelle in Paris the writer has been able to examine some of the glass described by Fouqué and to confirm his conclusions. The present material, while resembling it in some respects, differs in several important particulars, as will be presently shown.

---

* Compt. Rendus, cix, Jan. 1, 1889.

Morozewicz* has also described crystallizations resulting from the outflowing of glass from industrial furnaces; in this case large single crystals of wollastonite were formed. He mentions also rounded aggregates of fibrous diopside, but does not describe them definitely as of spherulitic structure.

Spherulites.—The most important kind of crystallization shown by the Kane glass-flow is in the formation of spherulites. The glass itself is an ordinary green bottle glass, pale greenish where thin and a clear, sea-green when a couple of inches thick or more. This is more or less filled with white spherical bodies which vary in size from that of very fine shot up to those which are nearly the size of an egg. These, and especially the largest ones, may be readily broken out of the glass, either as single spheroids, or as grouped or botryoidal masses. When extracted they have a smooth, thin, outer shell of glass which covers them like a skin. These solid bodies when broken open are white, with a pale greenish tinge, and are seen to possess a fibrous radiated structure. The fibers are extremely fine and thread-like, giving to the surface the luster of floss silk. This is true even in the largest. In some the cross section of the broken spherule, as it lies in the glass, appears radial but uniform, while in others changes in the conditions of crystallization, as the fibers grew outwardly from the center, have produced a series of concentric rings, such as are sometimes observed in the smaller spherulites in rhyolite. As many as ten of these rings, of almost perfectly circular form and of similar width, have been observed in one spherulite, and, thus mottling the silky sheen of the surface of the section of the divided spherulite, they have a moiré, or concentric, watered-silk appearance, and add greatly to its beauty. The structure, or consistency, of the spherulites varies greatly; some are so compact that they are composed almost wholly of crystalline material, while in others the thread-like fibers are relatively widely separated and the whole spherulite is saturated with the greenish glass. Thus, while the first form very solid white objects, the latter appear almost like misty or cloudy forms in the green matrix surrounding them, and the conchoidal fracture passes through the glass without reference to them nor can they of course be broken out and separated from it.

In another portion of the flow which formed a sheet about two inches thick the spherulites have a somewhat different character. Here they appear to be composed, not of tenuous fibers, but of distinct, rather thick, blades, $0{\cdot}5$–$1{\cdot}0^{mm}$ broad by 4^{mm} long, as may be seen by reference to figs. B and C in Plate I which represents them in very nearly natural size.

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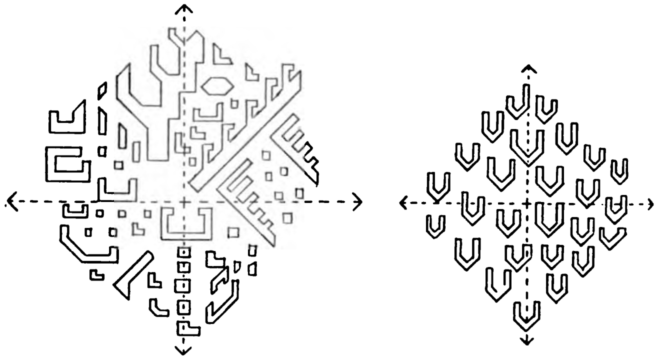
* Min. Petr. Mitt., xviii, p. 124, 1898.

They average about 7-8^{mm} in diameter. In addition to the regular spherulites various modifications of them exist in this place, as may be seen by reference to the plate. Some are composed of only a few blades, or even only two or three, radiating from a center in a star-like group, but with blades the same size and length as those of the more complete spherulites. The beauty of these white radiate and stellate crystallizations suspended in the clear sea-green glass is very striking, and the fact that they are thus suspended and did not fall to the bottom shows that at the time of their formation the molten glass was in too viscous a condition to permit of such movement, a fact whose bearing upon the question of their origin will be treated later. The bottom of this sheet of glass is composed of a layer of spherulites about 3-4^{mm} in thickness. Looking at the bottom surface itself it appears flat and smooth but so thickly covered with the radiate crystallizations of these spherulites, seen in half section, that they nearly everywhere coalesce, or are contiguous. The appearance recalls surfaces covered with radiate zeolites or frosted window-panes in winter. The upper surface of this layer presents a somewhat mossy appearance as the rounded, bladed, surfaces of the spherulites project into the glass. It is seen on the right hand side of figs. B and C in the plate. The white cloudy area near the top of the piece in fig. C is due to the internal reflection of light in the glass and nearly conceals a very fine spherulite. The blades composing these spherulites are small at the center where they unite and grow larger gradually as they extend into the glass. They are four sided with apparent right angles and are terminated by an oblique plane, but the crystallization is rough and imperfect. Close inspection of the photograph will show these details.

Mineral Composition.—The study of the mineral composing these spherulites in thin sections and in powdered grains under the microscope proves that it is artificial diopside. This is seen from the following properties: inclined extinction, c on *c* measured to a maximum of 39°; sections having parallel extinction show the exit of an optic axis on the edge of the field and that the plane of the optic axes lies in the clinopinacoid parallel to the length of the prism; by repeatedly measuring the width of the nearly square prisms as they lie in the glass their thickness is also obtained, and the birefringent color yielded by those having the maximum angle of extinction indicates that the maximum birefringence is about 0·03. The cross section of the prisms shows them to be nearly square, but they are too minute to show the cleavage parallel to the prismatic sides; the extinction bisects the angle. These are the properties of diopside and the physical determination was confirmed by qualitative chemical tests on material extracted from the glass which proved, in addition to the silica, the presence of traces of iron and alumina and abundant lime and magnesia. It is evident that a dolomite limestone was used in the making of the glass.

Microstructure of Crystals.—When studied under the microscope in powdered form it is found that the crystal blades, illustrated in the photographic plate, are very far from being the solid continuous crystals they appear. Close inspection of them with a simple lens, as they lie in the glass, proves them to have a parallel fibrous structure. The microscope shows them in length sections to consist of bundles of extremely slender rods or fibers. These are sometimes closely packed, sometimes separated by much more than their own diameters. They are surrounded by, or are cemented together, by the glass in which they lie. Sections across these fibrous bundles, or blades, prove that to a great degree they are not simple solid fibers, or rods, but are more or less hollow, or skeleton-like in form, and that groups of them have a similar crystallographic orientation. One of these is shown in the adjoining fig. 1. The directions of extinction in this are indicated by the broken arrow lines; these indicate the plane of symmetry in the compound or skeleton crystal and it is interesting that the directions of growth are along both pinacoidal and prismatic faces. Another type is shown in fig. 2; the growth here is along the clinopinacoid *b*, 010, and the prismatic faces; that along the othopinacoid being wanting. A number of different patterns of growth were observed but they are sufficiently illustrated by these examples.

Fig. 1. Fig. 2.



Figs. 1, 2. Skeleton crystals of diopside.

Chain Spherulites.—An interesting feature is the presence of chain spherulites along flowage lines, as illustrated in the photographic plate fig. A. The white lines are composed of layers of innumerable minute spherulites, while the darker layers between are of clear green glass free from crystalline products. Examination with a lens reveals the fact that almost without exception these lines are composed of a chain, or layer, of single spherulites. Generally they are so closely crowded that they coalesce to a considerable extent, less often they touch at the circumference, and in some places they appear quite regularly spaced but separated by areas of glass, generally not wider than their own diameter. Viewed with the lens from above, a layer appears like one of minute white pills sifted into the glass, innumerable in number and spread without order, here thickly clustered, there more thinly distributed. The average size of these spherulites is $0{\cdot}5$–$0{\cdot}6^{mm}$ and they do not vary much from it. Under the microscope in thin section they appear like the spherulites of feldspar seen in acid lavas, so much so that it is almost difficult to believe one is not dealing with a section of rhyolite. Although snow-white in the glass, and also as seen by the microscope with reflected light from the section, they appear of a light leather-brown color by transmitted light. With a low magnification the central part of the spherulite looks uniform and homogeneous, the fibrous character appears more evident as the outer boundary is approached, and the outermost zone is composed of distinct, branching, fibrous rays. With high magnification the central part is also resolved into masses of excessively fine, tenuous, matted fibers. At the center, where these fibers are cut perpendicularly, they appear as mere points.

When the structure of these bodies is revealed by the use of crossed nicols, it is seen that they are not formed uniformly of single fibers radiating from a common center, but rather of groups, or bundles, of fibers somewhat radially divergent, like brooms, or brushes; closely stellate groupings of which form the spherulites. Thus they repeat on a minute scale the examples shown in B and C of the plate and described in the preceding section. Like other spherulites they show a black cross, which is sometimes in one bundle, or brush, parallel with the planes of the nicols and sometimes, as the spherulite is revolved and a new brush comes into position, is somewhat inclined, proving that in each brush the majority of the minute fibers tend to have orientated positions and thus make a compound skeleton crystal. This is also like the larger ones described and figured in the preceding section.

The light leather-brown color of the sections of these spherulites is a curious feature. It is strongest in the central areas where the fibers are finest and most closely packed; at the periphery, where they are coarser and more individualized, it is wanting. With a very high magnification of the center and parallel light from below, it disappears. With low-powered objectives it is present, whether the lower nicol is present or not. The spherulites of feldspars in acid volcanic lavas often show the same phenomenon of brown coloration, and so do the closely packed aggregates of minute scales of kaolin in feldspar. Since in all these cases the component mineral fibers, or scales, are white, that is to say colorless, this effect cannot be due to a pigment, but must be an optical phenomenon due to the absorption of light. An explanation of this may be somewhat as follows: Angular fibers or scales of a colorless mineral lying in all positions in a medium of lower refractive index may act as prisms to rays of light passing through them. The rays of white light would be then decomposed into their primary colors, and the violet rays more inclined than those of the red. On passing upward and striking inclined surfaces of new fibers, or scales, the light in the violet end of the spectrum, on account of its greater inclination than that towards the red end, would tend in greater measure to suffer total reflection and be absorbed, while the less inclined rays of the red and yellow would pass through and, illuminating the dark areas of total reflection, give the fibrous mass the brown tone. This explanation is based essentially on the same principle as that given by von Federov* for the pseudo-pleochroism which he observed in minerals containing thin parallel laminations. Only in this case there is no parallelism, the angular fibers lie in all directions, hence there is no apparent pleochroism and the mass appears of the same brown color in all positions and with, or without, polarized light.

It may be that in this lies the explanation of the brown and gray colors and pleochroic effects observed in spherulites in certain volcanic glasses by Cole,† but a search through the literature has not yielded to me any discussion of the frequent brown color of spherulites (or kaolin) though so commonly observed. Probably it is usually ascribed, if noticed, to some ferruginous pigment, to which in some cases it is undoubtedly due.

Some other features of interest which these spherulites show are as follows: In some, especially larger ones, hollow cavities appear; others have no cavities but a pronounced crack running through the center; often this crack passes along through several of them, and it is always rigorously parallel to the direction which the chain or line of spherulites makes (line of flow). Where one has a cavity the ones immediately adjacent are apt to have the crack. In some places this crack has opened quite widely and an ellipsoidal or lenticular cavity is produced, bordered on either side by half spherulites extending into the glass. The bearing of these facts is discussed in a later place.

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* Min. Petr. Mitt., xiv, p. 569, 1895.

† Quar. Jour. Geol. Soc., xliv, p. 302, 1888.

Another feature, quite similar to what is often seen in acid volcanic glasses, is the presence of cracks in the glass immedidiately surrounding the spherulites. These commonly start out from the edge of the spherulite, and especially from the place where two tend to intersect, and then curve, sometimes splitting and forming a Y. Usually after a short curve they stop, but quite often they continue in a long curve concentric to the outer surface of several adjacent spherulites and removed from it a small fraction of the total diameter of one of them (see fig. 3). It is owing to these concentric cracks surrounding them that the larger spherulites may be readily broken out of the glass and then appear with a thin, smooth skin, like varnish, coating them.

Fig. 3.

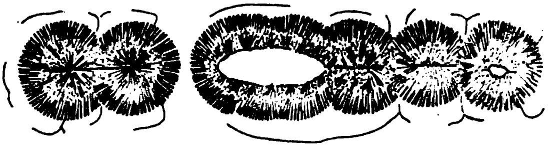

Fig. 3. Spherulites with cavities and cracks.

Stony Material.—In the material represented in the collection there are some pieces of a white lithoidal or porcelain-like appearance. They have a light greenish tone of color and a deeper green by transmitted light. A number of small vesicles or gas pores are here and there seen in the material. Under the microscope it is found to consist of glass filled with microlites; some of rather short, minute prisms of diopside with inclined extinctions and masses of feathery and fern-like forms of the same substance. There are also minute fibers whose extinction appears parallel and whose exact nature is doubtful.

Obsidian.

One of the most interesting features of the collection is the presence of several specimens of jet black artificial obsidian, appearing quite similar in color, luster, and fracture to the natural obsidians from the Yellowstone Park, Mono Lake, Lipari Islands, and other well known localities. Flowage lines or directions through the mass are indicated by parallel chains of little points around which the glass has a minute but different fracture and which thus interrupt the broad, smooth surfaces of the usual conchoidal areas.

The appearance of this black glass is so entirely unlike that of the ordinary light-green and transparent bottle glass that formed the flow that it is difficult to believe it is merely a modification of it, though positively so stated. It is, however, as will be presently shown, a curious modification of *a* light-green transparent bottle glass, though whether of the same melt as that which has been previously described as containing the spherulites seems doubtful. The doubt rests on chemical evidence. The first glass contains, as mentioned, only a small amount of iron, and a considerable proportion of magnesia, and diopside has crystallized from it; the qualitative analysis of the obsidian indicates much more iron, and while there is abundance of lime, magnesia is present only in minutest traces and as a result wollastonite has crystallized out in a particular layer, as will be described later. Unfortunately, in the lapse of time since the material was formed the possibility of obtaining more exact information concerning it and the conditions under which it was produced have been lost. If the statement accompanying the collection is to be trusted, then magmatic differentiation must have occurred, which seems hard to believe.

Considering the black color, it seemed at first as if the glass must have been of some other melt into which some unusual ingredient had entered which colored it black, or if a part of the flow, then one which had in some way imbibed a coloring constituent. Close inspection of a piece of this obsidian shows, however, that in a place where there are fractures, or cracks, penetrating it, if the mass is so turned to the light that the rays entering it are reflected back from the internal surface of the crack to the eye, the black color disappears and the glass, between the crack and the eye, assumes its normal sea-green transparent aspect.

The black color is due, then, not to a chemically diffused coloring matter, so to speak, in the sense that iron compounds color glass green, manganese purple, or cobalt blue, but is a mechanical effect of some kind, owing to which that light which strikes it and is not immediately reflected from the outer surface, penetrates it and is absorbed.

Many or most natural obsidians which appear black are found in thin section to be composed of a colorless glass, swarming with specks, or trichites, whose exact nature is unknown, but which many believe to be of magnetite. The idea involved is this: An obsidian is formed because the effusion and cooling have been so rapid that the ordinary rock constituents have had no opportunity to begin to crystallize before the mass stiffened. But experience also shows that, in general, the more rapid the cooling the greater the number of centers of crystallization which will be set up. Now if anything should start to crystallize in magma under such conditions it would be the magnetite, ordinarily the earliest mineral of importance to form, and it would be therefore distributed through the glass in the shape of the finest dust acting megascopically as a mechanical pigment and coloring it black. The red color that many obsidians show may then be due to the complete oxidation of the magnetite to ferric oxide.

On the other hand, a study of a number of sections of various obsidians, and also of the literature, seems to indicate that the color may not be wholly due to magnetite. Zirkel,* in discussing it, considers that it is sometimes inherent in the glass (chemical so to speak) and is sometimes due to inclusions of minute size, which he describes. In the latter case the glass is colorless, and in the study of several obsidians of this character the writer has observed that the microlites, or trichites, have a higher index of refraction than the surrounding glass, as shown by Becke's method. On lowering the objective beyond the focal point they appear black, on raising it above they become illuminated and appear colorless. Consequently they are transparent and not magnetite. The greater the number of these incipient crystallizations there are, the blacker and less transparent the glass appears megascopically. The black color in this case then is due to light absorption. In one case where the slender microlites were arranged in parallel positions in streams, it was noticed that the section possessed a distinct pleochroism; when the ray vibrated across these streams it appeared colorless; when the long diameters were parallel to the ray it was distinctly brown. This is an effect of light absorption similar to that previously described under spherulites and doubtless produced in the same way. The black color of many obsidians then appears to be caused by the dispersion, total reflection, and absorption of light due to the presence of innumerable hosts of minute crystalline bodies of a higher refractive index than the glass in which they lie, such crystalline bodies being themselves colorless.

In the case of the artificial obsidian of Kane, with magnifications of 540 diameters, the microscope reveals the presence of bodies of indeterminate nature. They are so minute that no definite shape can be assigned to them, but they give a vague impression of being rudely octahedral. On lifting the objective they become strongly illuminated, on lowering they appear black. Thus they are transparent and of a higher index of refraction than the glass. While everywhere freely sprinkled through the field of view, as the stars appear at night in the sky, they cannot be said to swarm in the sense that, with reference to their own diameters, they closely approach one another. They exert no perceptible action on polarized light. To the absorption of light caused by the presence of these minute bodies, as with some natural obsidians, the black color of this variety of the Kane glass is ascribed.

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* Lehrb. d. Petrog., vol. ii, p. 271, 1894.

Partly Crystallized Obsidian.—In one place there is a layer of the obsidian about 3 inches thick, which has partly crystallized. The black glass described above makes a rather clean and sharp contact with it. It is not now known whether this layer was above or below the pure glass one, but as it contains impurities on the side opposite the glass, and also on general principles, it is assumed as the bottom part of the obsidian. In the specimen it has a stony, not glassy, appearance; is of a very dark to blackish gray color, and is seen to be composed of a sort of felt of innumerable small slender-bladed crystals $2–4^{mm}$ long, which have a tendency to be arranged parallel to the extension of the layer. It has something of a rough resemblance to some hornblende schists. There is no schistosity in the fracture however, which is rough and hackly. The thin section under the microscope is a very interesting one. It is composed of a pale brown glass, filled with beautiful crystallizations of the mineral wollastonite. While in general the mineral is developed as usual in long columnar forms, or plates parallel to the axis of symmetry, its growth has also been in such aggregates of sheaf-like, rosette-like, or feathery forms, that according to the way these are cut different effects are produced. The simplest case is shown in fig. 4, which gives a section parallel to *b* (010), across one of the bladed crystals. The faces in the zone of *a* (100) ∧ *c* (001) are very sharply developed, as may be seen from the following table of angles measured against the cross-hairs:

Fig. 4.

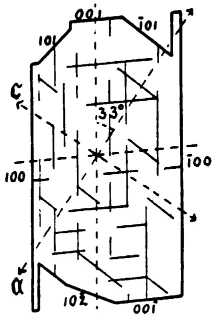

Fig. 4. Wollastonite, section parallel to *b* (010).

	Meas.	Calc.
β, $a\ (100) \wedge c\ (001)$	84°	84° 35′
$a'\ (\bar{1}00) \wedge t\ (\bar{1}01)$	50° 30′	50° 26′
$a\ (100) \wedge v\ (101)$	42° 30′	44° 33′
$a\ (100) \wedge \alpha\ (10\bar{2})$	70°	69° 55′

The calculated angles are those given by Grosser* and the agreement is very good, except in *v* (101), which was not so well developed as the other faces. The three cleavages parallel to 100, 001, and $\bar{1}01$ are excellent, as represented in the figure, their excellence being in the order given. The plane of the optic axes lies in the clinopinacoid and the bisectrix $\mathfrak{a}$ makes an angle of 33° in the acute angle β with the vertical axis; Des Cloiseaux gives 32° 12′. The optical character is negative, $\mathfrak{a}$ being the acute bisectrix. Since, according to Des Cloiseaux, the optic angle in air $2\,E =$ about 70°, it follows that one optic axis emerges almost perpendicular to *c*, 001, the other at an angle of about 16° to *a* (100). Since both of these are good cleavages, it follows that when one examines the powder made by crushing the material, in convergent light under the microscope with crossed nicols, almost invariably each fragment exhibits the locus of an optic axis either just in, or just off, the field of view. Since the *a* (100) cleavage is the best, it is mostly the latter case that obtains and in the blades the long direction is the one of least elasticity.

While these crystallographic and optical properties prove the nature of the mineral, its identity was confirmed by the fact that, when powdered, it dissolves readily in hydrochloric acid and yields gelatinous silica.

It will be noted in the drawing of the crystal shown in fig. 4 that the *a* (100) faces are extended in a thin plate forming re-entrant angles; commonly these thin plates extend far beyond the main crystal and from each of the four corners, tapering off indefinitely; the cross section of the whole then shows an H with the vertical legs greatly extended. There may be other cross connections producing ladder-like affairs. It is also to be recalled that these extend as sheets perpendicular to the plane of the drawing, or along the *b* axis. Moreover the sheets are often curved and numbers of these extended plates are grouped into sheaves or rosette-like groups, and thus a variety of patterns are produced as these are cut by the section at various angles. The individual filaments as they appear in the section are commonly curved; if examined with a very high power it is seen that the curve really consists of a series of short minute straight pieces of crystal with wedge-shaped cracks between, continuity obtaining only along one edge. By this curving, and by repeated branching, arborescent, or plumose, forms are produced, and in places the glass between crossed nicols appears filled with them and seems like masses of magnificent ostrich plumes thickly scattered, the beauty of whose effect is greatly heightened by the use of the sensitive tint, which turns them brilliant blue and yellow.

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* Zeitschr. f. Kryst., xix, p. 603.

These plumose forms, which are of remarkable delicacy and perfection, resemble the growths of augite in basaltic glass from Hawaii, described by E. S. Dana*; they differ from the growths in the pitchstone of Arran in being much larger, more perfect, and in the curved or curled character of the stems, thus resembling plumes rather than ferns. They never form complete spherulites, though in places the thickly-grouped, feather-like bunches partly resemble them.

Spherulitic Crystallization.

The vast majority of the natural spherulites occur in acid, that is to say, siliceous volcanic glasses, and are composed of quartz, or feldspars, or of these two minerals in various proportions. The reason for this is because it is especially in magmas of this nature that the relation between viscosity of magma and crystal growth, which is necessary for spherulitic crystallization and which is discussed later, is apt to occur. Spherulite crystallizations may occur in basic magmas and are known in the rocks called variolites,† but so far as the writer has been able to discover, no discussion of spherulites, as such, has been made which was not primarily based on material of the kind referred to. It is natural, therefore, that in these discussions the chemical character of the magma involved and the nature of the component minerals are largely held responsible as determinant factors for spherulitic crystallization. Since such natural magmas contain, as is well known, volatile constituents, especially water vapor, a considerable rôle has been ascribed to its agency in this connection. Thus Cross‡ ascribed the origin of the spherulites in a rhyolite studied by him to the presence of a colloidal condition in the magma, due to the antecedent formation of masses of opaline silica containing the elements of feldspar, which caused their formation and globular form. Iddings§ also, in his earlier discussions of spherulites, suggests that water vapor plays an important rôle in rendering certain places in the magma less viscous and therefore more susceptible to molecular movement and crystallization. This would explain the formation of crystalline spherulites in some places, while the surrounding magma solidified as glass although at the same temperature. He says: "Hence we may conclude that the influence of the absorbed water-vapor is to render the molecular mobility of the molten magma greater at a given temperature in proportion to the amount of hydration, thus permitting the crystalline arrangement of the molecules in places of greater hydration, while the surrounding less hydrated portions are becoming too viscous."

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* This Journal, xxxvii, 441, 1889.

† Pirsson, Petrog. of Igneous Rocks of Little Belt Mts., 20th Ann. Rep. U. S. Geol. Surv., Pt. III, p. 532, 1900.

‡ Constitution and Origin of Spherulites in Acid Eruptive Rocks, Bull. Phil. Soc. Wash., xi, 411, 1896.

§ Bull. Phil. Soc. Wash., vol. xi, p. 446, etc., 1891.

In his latest discussion of spherulitic crystallization, Iddings* again refers the conditions controlling it in acid volcanic glasses to varying amounts of water vapor—as "probably dependent on viscosity, as affected by the gas contents of a magma." In these discussions, however, the underlying idea appears to be not so much an explanation of the assumption of the spherulitic *form*, or habit of growth, as of the production of local conditions which would favor crystallization and permit the formation of one component rather than another, for in spherulitic growths in the natural volcanic glasses one must deal with quartz and feldspar.

Spherulitic crystallization in the ultimate analysis is a question of crystal form or rather *habit.* The essential thing in a typical spherulite is that from a common center crystals grow in all directions whose elongation is excessive as compared with their breadth and thickness. They may be straight rods, or branching rays, or blades, or assume arborescent shapes, all of which occur in the Kane specimens, but always tending to elongate forms, thickly crowded. The suggestion of Cross tends to assume that the spherical shape or rather area was defined before crystallization actually occurred and is thus an explanation rather of the outward form than of the inward structure. It seems highly probable that the degree of hydration in the natural acid glasses affecting the viscosity, as suggested by the writers above, plays an important rôle in determining the conditions and places for spherulitic crystallization, but in the Kane glass this agency was not present and the complication of having two mineral substances to deal with is also wanting. The question here is simply one of the conditions which determined the assumption of a certain kind of crystal habit, and the answer, in the writer's opinion, is to be found in the degree of viscosity which had been attained at the time when the saturation of the solution with the diopside molecule reached the crystallizing point. Iddings† states that the habits of crystals depend in a large degree on the viscosity of the magma, long slender prisms and branching shapes being commonly developed when it is very viscous, though he does not explain why this is so. The writer offers this explanation for the slender fibers in the spherulites of diopside in the Kane glass. The pyroxene has a prismatic cleavage and is elongate in the direction of this cleavage. It is not singular in this respect, for most minerals tend to be elongate, or columnar, in the direction of pronounced cleavages. In the direction normal to the cleavage faces the molecular network has a lesser amount of cohesive attraction than in other directions and hence the cleavage. We may therefore imagine that during the process of growth the amount of molecular tension or pull exerted by the crystal upon the unorientated molecules in the magma is greater toward the end face than toward the prism, or cleavage, faces. Hence the supply of molecules upon it is more rapid and the crystal grows faster in this direction. If now the viscosity of the magma rises to such a degree that the tension toward the side faces is not sufficient to overcome it and orientate the molecules while that upon the end face is sufficiently great, then the crystal will extend itself like a long rod, or fiber, until the growing viscosity puts a stop to further progress in this direction also. The crystallizing effect of the fiber end would also be aided by the fact, that as the molecules fall into position in the geometric network, or change from the liquid to the solid state, a certain amount of heat is liberated, tending to increase the mobility of the still unfixed adjacent molecules and to render them more susceptible to crystallographic orientation. The crystals then, like a wire with a hot end, bore out into the stiffening magma in all directions, and as conditions are uniform about them they cease simultaneously and the globular shape results. This relation of habit between viscosity and cohesive attraction is also well illustrated by the wollastonite crystals in the dark glass. They extend indefinitely along the *b* axis perpendicular to which there is no cleavage and are also tabular to the *a* (100) face, parallel to which the best cleavage occurs. In the fibers of feldspar in spherulites in the volcanic rocks the elongation in the majority of cases is parallel to the clino axis, the direction of the two prominent cleavages, The instances cited where the elongation is parallel to the *c* axis* would tend to show that the molecular attraction to the *c* (001) face in orthoclase is greater than that to the *b* (010) face. The fact that large crystals and especially Carlsbad twins are often tabular or elongate on the *c* axis also shows this. It is generally considered that the cleavage *c* (001) of orthoclase is better than that of *b* (010), and this would appear to make these cases an exception to the general rule. It is not clear, however, judging from the views of the writers previously stated, that viscosity is the only factor to consider in these cases, as it is in the Kane glass, as a delicate balance between several different factors may have induced this particular form. Nor does the writer wish to affirm as a positive rule that in all minerals the attraction causing growth is less towards a pronounced face of cleavage than in other directions. It does, however, appear to be a rather general one.

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* Igneous Rocks, vol. i, pp. 231, 233, 1909.

† Igneous Rocks, vol. i, pp. 206, 216, 1909.

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* Iddings, Spherulitic Crystallization, Bull. Phil. Soc. Wash., vol. xi, p. 456, 1891.

In addition to the elongation of the fibers in spherulites there is also the branching to be taken into account. The more rapid growth of the corners and edges of crystals, due to their commanding a larger portion of the space which is supplying the crystallizing material and thus producing branching and skeleton growths, was brought to attention by Lehmann* and further elaborated by Rosenbusch† and needs no further discussion here. In the treatment of the subject by these authors, however, it is tacitly assumed that the molecular attraction towards all faces of the growing crystal is the same, or at least there is not mentioned anything to the contrary, and the view previously expressed by the writer, that this may be different on different faces, brings into play another factor.

That the molten glass had attained a considerable degree of viscosity before crystallization began is clearly indicated by the spherulites seen in figs. B and C of the plate, since it was great enough to support these denser bodies and prevent them from sinking to the bottom.

That the formation of the spherulites was a comparatively rapid process, after crystallization once started, is plainly shown by their occurrence in the manner figured in A of the plate. They were not present, of course, in the molten glass in the furnace before breakage occurred, and their appearance here in flow lines proves they had formed before flowage motion of the glass had ceased. However long a time viscous flowage may continue in larger masses of lava, in this small body of glass it must have had a relatively short period.

From the foregoing discussion it appears that the production of spherulites in an anhydrous molten glass depends upon crystallization starting from a center and proceeding outwardly in all directions at a time when the molten solution had attained such a degree of viscosity as to control the crystal habit and also upon the composition being such as to produce minerals which naturally grow in columnar forms. The time interval between this point and that where the fall of temperature increases the viscosity to such a degree as to prevent further molecular movement evidently controls the size of the spherulites. In the case of the huge spherulites described by Cross‡ from Colorado this time interval must have been relatively long.

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* Ueber das Wachsthum der Krystalle, Zeitschr. f. Kryst., i, 462, 1877.

† Phys. der Min., 1885, p. 26, 4th ed., vol. 1, 361, 1904. ‡ Loc. cit.

In a sheet of molten glass the planes of cooling descend vertically into the mass so that variations of temperature from point to point become much more marked in this direction than in a horizontal one. It is also true that in the change from the liquid to the solid condition a more or less considerable contraction of volume ensues. Further, the force of crystallization is very powerful within the distance in which it acts,* and in the final stage of viscosity before the capability of molecular movement ceases the tension on the growing crystal faces must be very strong and, *per contra*, on the adjacent areas of unorientated molecules. Taking these facts into consideration, it is clear that especially toward the end of the process of spherulitic crystallization, these bodies and the glass surrounding them will be subjected to stresses which are most marked in vertical directions. Unable to withstand the tension, they may rupture, giving rise to horizontal, or longitudinal, cracks or even be pulled apart so that ovoid, or spherical, cavities are opened within them, as illustrated in fig. 3. Or the tension between them and the surrounding glass may be relieved by tangential, or radial, cracks in the latter, as also illustrated and described. Thus the layers of spherulites spread through the glass in bands by flowage become elements of inherent weakness and along them it splits into plates and thus has a laminated structure. This phenomenon is also noticed in natural rhyolite glasses, like those from Lipari and the Yellowstone Park, which cleave readily along the bands of spherulites. Iddings,† in discussing the laminated nature of such rocks, attributes it to non-homogeneity in different parts of the magma, produced by variable amounts of contained water vapors, which unlike portions by the spreading out action of flowing lavas become distributed in thin sheets. Hence arise layers of different degrees of consistency, crystalline character, etc., which condition the banded structure and cause lamination. The Kane glass, however, shows that the same lamination, though not perhaps in so high a degree, can be formed in the cooling of an anhydrous magma and that the water vapor, except where it causes layers of bubbles, as in pumice, must be an indirect rather than a direct agent in producing lamination in that it promotes more favorable conditions for crystallization.

Differentiation.—In the clear glass containing relatively few small spherulites there is a non-homogeneous quality which shows itself by drawn out streaked lines and layers, these being nowise different in color or consistency, but having different refractive indices, and thus becoming visible by their action on light, in the same manner that heated air-currents are visible above a source of heat, or differing currents of salt laden solutions are seen in a liquid. These streaks are small and fine and are parallel to one another, and to the chains of spherulites, in the direction of flow. Since the refractive index varies in the different layers there must be a difference in composition to occasion it. The difficulty of obtaining glass of uniform composition, through a tendency to separate into unlike portions, is one well known to makers of lenses and other users of optical glass and has been frequently described. It needs no further mention here beyond the comment that this case adds another to those which have been cited by others as a proof that the instability of molten silicate solutions furnishes a presumptive proof of the possibility of magmatic differentiation on a larger scale.

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* Becker and Day, Linear Force of Growing Crystals, Wash. Acad. Sci. Proc., vol. vii, p. 283, 1905.

† This Journal, vol. xxxiii, p. 43, 1887; Igneous Rocks, vol. i, p. 243, 1909.

If we accept the statement, which cannot unfortunately be now verified, that the black obsidian is really a part of the same glass flow, a more striking instance of differentiation is shown in that the clear glass is rich in magnesia and poor in iron oxide while in the obsidian the reverse is the case. This difference explains very clearly why diopside crystallized out in the one and wollastonite in the other. But such a movement, provided we suppose the original molten solution to have been homogeneous, whereby magnesia and ferrous oxide are concentrated in opposite directions, while one would hesitate to say it was impossible, from all our experience gained in the study of rock-masses in which these oxides move together, seems very unlikely to say the least. And on the other hand, we do not know, in the production of glass on so large a scale, whether a sufficiently high temperature was maintained long enough to permit the molten solution to assume conditions of uniformity throughout its mass, if, on account of a difference of materials used in the making, uniformity was not present to begin with. Viewed from this standpoint, it is possible that the obsidian was part of the same flow. At all events, the material seems to indicate the possibility of obtaining in this direction, artificially, some light on the, at present, mysterious process, or set of processes, known as differentiation.

Composition of Minerals.—The use of the terms diopside and wollastonite in this paper is of course only a general one and it is not assumed that these substances are necessarily present in a pure condition. From the splendid results which have been achieved in recent years by Dr. Day and his co-workers in the Geophysical Laboratory of the Carnegie Institution concerning the properties of the lime and magnesia silicates, and the conditions under which they are formed, and which have been published in this Journal,* it has been shown so clearly that diopside and wollastonite, as produced from molten solution, may contain variable amounts of lime and magnesia metasilicates in solid solution, that it would seem quite possible that the diopside in the Kane glass is far from being pure in composition. The analytical test proves that the wollastonite is relatively a pure compound, and the optical data, so far as they go, agree with this view.

It is evident from the works quoted that the temperature of the glass, when the wollastonite crystallized, must have been lower than 1190°, since this is the inversion point of the mineral to pseudo-wollastonite, which alone exists above that temperature and up to 1512°, its melting point. The melting point of diopside is 1380° and the temperature of the molten solution was therefore originally above this point; this of course is to be expected, even though a flux is used to help carry the quartz sand and lime carbonate into solution.

Summary.—The study of the accidental flow of molten bottle-glass at Kane, Penn., has brought out the following chief points:

That spherulites of varying size and character and consisting of diopside may be formed in an anhydrous molten solution by rapid cooling.

That the spherulitic type of crystallization appears to be conditioned by the relation of crystal habit and properties to the viscosity of the magma. The spherulites are of rapid growth.

That the brown color, which many spherulites exhibit by transmitted light, is a phenomenon of light absorption.

That obsidian may be artificially produced from a clear glass and that its black color is a phenomenon of light absorption.

That artificial wollastonite may exhibit certain characters which are described.

Sheffield Scientific School of Yale University,
New Haven, Conn., April, 1910.

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* Day, Shepherd and Wright, The Lime-Silica Series of Minerals, vol. xxii, pp. 265–302, 1906. Allen, White and Wright, On Wollastonite and Pseudo-wollastonite, Polymorphic Forms of Calcium Metasilicate, vol. xxi, pp. 89–108, 1906. Allen, White, Wright and Larsen, Diopside and its Relation to Calcium and Magnesium Metasilicates, vol. xxvii, pp. 1–47, 1909.

ART. VIII.—*The Inversion of Temperature Amplitudes and Departures in the United States;* by FRANK H. BIGELOW.

The Phenomenon of Temperature Inversion.

IN several of my papers on the temperatures of the United States, I have given preliminary data showing generally that there is a distinct tendency to invert the temperature variations in the United States relatively to the solar conditions as given in the annual numbers for the frequency of the sunspots and solar prominences. These are, this Journal, December 1894, inversion of temperatures in the 26·68 day solar magnetic period; Weather Bureau Bulletin No. 21, 1898, Solar and Terrestrial Magnetism, pp. 121 and foll.; Monthly Weather Review, November 1903, Synchronism of the solar prominences with the terrestrial barometric pressures and the temperatures. These papers indicated that the response to a change in the solar energy when received at the earth is by no means simple, but that the terrestrial effect is much complicated by the circulation of the atmosphere, whereby opposite temperature effects are produced in different latitudes. Thus, an increase of solar action produces an increase of temperature in the Tropics, but a relative decrease in the temperate zones. This view was explained more fully in two papers, this Journal, May, 1908, and April, 1910. Bulletin S, U. S. Weather Bureau, 1909, contains the temperature data of the United States, 1873–1905, reduced to a homogeneous system, which is continued in the Annual Reports of the Chief of the Weather Bureau, and these temperature data have been used in preparing Table I of this paper. We have the independent records of upwards of 100 stations from which the annual departures on the 33-year normal are computed. These annual departures were entered on base maps of the United States, and lines of equal departures were drawn. This system of departures for the United States is so smoothly developed that it is very easy to draw the lines of equal temperature variation. There is one map for each month, and one for the year, from January, 1873, to December, 1909, making $37 \times 13 = 481$ separate charts, upon each of which there are something like 100 entries of the temperature departures. An example is given for May, 1896. Each entry on fig. 1 is found by subtracting the 33-year normal of the station from the monthly mean given in the Bulletin S table for the several stations. An inspection of these 100 independent values of the departure shows that there is a remarkably harmonious agreement among them, which implies that the temperature system of the United States is really homogeneous for 37 years, and that the data derived from the large cities is indistinguishable from those obtained in localities affording more favorable exposure for the meteorological instruments. Similarly, the 481 charts available have spread out the history of the mean monthly temperature variations from the 33-year normal for the period January, 1873, to December, 1909, inclusive, and it is our problem to analyze and discuss this valuable material.

The Temperature Departures for the United States.

These charts are available for several purposes. (1) They permit the adjustment of the temperatures of a short record station to the 33-year normal by the following process: Take the means of the short record series of temperatures month by month, and their departures (v_1-v_s); take the departures by scaling from the charts for the station during the same interval of time $(v-v_0)$; if the sum of the differences, $\Sigma\,[\,(v_1-v_s)-(v-v_0)\,]=0$, equals zero, it follows that the mean temperature of the short series is the same as that of the 33-year normal series, because the departures average the same amount; if these mean sums are not equal it is easy to compute a value for v_s which will make them equal, and then $v_s=v_0$. The departures $(v-v_0)$ are derived from the charts of long record, while those for (v_1-v_s) are derived from the station short record, so that it is only necessary to adjust the latter to the former by correcting v_s in such a way as to give the same system of departures for the station record that appears on the charts on the average.

(2) It is evident that these charts constitute the record for a small area of the earth's surface of the temperature changes going on over continents and oceans in both hemispheres, eastern and western, or northern and southern, such as meteorologists require for the study of problems in the world-departure of temperature. The Weather Bureau now possesses tables from which correlative variation charts can be constructed for the barometric pressures, the temperatures, the vapor pressures, and the precipitation in the United States, 1873 to 1910, and they will be utilized in all important world problems of the atmosphere for many years to come. Only those who have performed the great labor of reconstructing the massive records in meteorology for the United States for this period of 37 years can appreciate the work that has been accomplished in this respect. It now gives us a very solid foundation for studies of every description in solar and terrestrial physics, and it is hoped that similar data will soon be furnished by other well-organized weather services.

TABLE I.—THE TEMPERATURE DEPARTURES FOR THE UNITED STATES, 1873–1909.

Year	Jan.	Feb.	Mch.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Sums	Diff.
1873	+12	+14	+24	+1	+2	+48	+12	+35	+2	+1	+10	+20	+181	471	−109
	−42	−3	−20	−54	−32	−2	−4	−3	−40	−40	−40	−10	−290		
1874	+60	+30	+20	+4	+32	+40	+82	+28	+15	+12	+14	+10	+297	426	+168
	−1	−8	−15	−64	−3	−1	−2	−9	−10	−6	−3	−7	−129		
1875	+6	+1	+3	+4	+18	+18	+15	+1	+1	+25	+12	+75	+179	757	−399
	−145	−144	−63	−54	−4	−12	−15	−30	−36	−25	−48	−2	−578		
1876	+80	+75	+3	+10	+12	+18	+28	+35	+5	+10	+6	+1	+283	628	−62
	−5	0	−95	−12	−7	−8	−2	−15	−27	−35	−24	−115	−345		
1877	+16	+144	+26	+5	+8	+12	+27	+30	+24	+12	+9	+128	+441	642	+240
	−24	−5	−36	−24	−32	−20	−1	−1	−3	−24	−28	−3	−201		
1878	+70	+144	+165	+64	+6	+20	+49	+52	+10	+5	+20	+1	+656	842	+470
	−12	−5	0	−2	−28	−17	−1	0	−18	−18	−5	−80	−186		
1879	+23	+42	+80	+25	+42	+18	+37	+10	+18	+72	+20	+16	+403	602	+204
	−17	−20	−1	−12	−6	−4	−1	−8	−26	−1	−13	−90	−199		
1880	+156	+63	+20	+21	+45	+20	+2	+12	+3	+1	+1	+2	+346	795	−103
	−2	−18	−35	−24	−12	−5	−9	−15	−25	−10	−150	−144	−449		
1881	+6	+22	+18	+20	+62	+35	+28	+38	+54	+45	+14	+95	+437	799	+75
	−72	−84	−30	−42	−1	−10	−7	−12	−20	−23	−40	−1	−362		
1882	+49	+98	+35	+16	+2	+12	+9	+11	+9	+35	+10	+14	+300	524	+76
	−14	−24	−18	−14	−44	−8	−15	−10	−7	−20	−25	−25	−224		
1883	+2	+25	+20	+8	+1	+20	+15	+6	+10	+20	+30	+38	+195	551	−161
	−90	−72	−24	−20	−50	−8	−6	−12	−30	−36	−6	−2	−356		
1884	+2	+35	+15	+2	+22	+22	+12	+5	+30	+48	+11	+7	+211	590	−168
	−57	−40	−20	−30	−12	−20	−18	−22	−24	−4	−6	−126	−379		
1885	+5	+24	+40	+20	+7	+4	+12	+3	+8	+12	+40	+42	+217	544	−110
	−80	−66	−45	−6	−21	−25	−5	−30	−13	−25	−3	−8	−327		
1886	+3	+72	+3	+18	+35	+9	+20	+16	+7	+30	+2	+24	+239	630	−152
	−96	−20	−36	−15	−4	−22	−9	−3	−11	−18	−85	−72	−391		
1887	+24	+42	+54	+15	+60	+30	+40	+5	+10	+9	+14	+4	+307	604	+10
	−72	−70	−19	−8	−1	−4	−2	−14	−12	−39	−8	−48	−297		
1888	+6	+84	+1	+45	+12	+12	+15	+9	+30	+12	+11	+42	+279	664	−106
	−112	−9	−90	−10	−43	−7	−6	−20	−30	−30	−22	−6	−385		
1889	+48	+2	+84	+45	+7	+18	+12	+15	+3	+18	+13	+135	+400	676	+124
	−25	−45	−9	−1	−18	−32	−15	−17	−40	−32	−39	−3	−276		
1890	+62	+65	+7	+15	+16	+25	+24	+2	+6	+2	+72	+55	+351	611	+91
	−48	−15	−40	−3	−38	−7	−8	−29	−30	−16	−1	−25	−260		
1891	+102	+40	+1	+31	+9	+7	+3	+13	+45	+13	+14	+65	+343	707	−21
	−24	−75	−75	−6	−35	−22	−42	−20	−3	−22	−25	−15	−364		
1892	+9	+85	+18	+4	+2	+11	+8	+7	+22	+15	+16	+2	+199	528	−130
	−85	−1	−32	−30	−81	−20	−15	−12	−12	−10	−27	−54	−329		
1893	+32	+12	0	+20	+1	+25	+15	+3	+10	+4	+2	+35	+159	582	−264
	−60	−63	−60	−70	−33	−15	−4	−24	−22	−22	−30	−30	−423		
1894	+32	+7	+57	+30	+20	+25	+26	+18	+15	+28	+30	+48	+336	556	+116
	−29	−64	−10	−2	−10	−25	−11	−20	−12	−3	−18	−16	−220		
1895	+2	+16	+18	+45	+15	+15	+1	+10	+30	+7	+7	+12	+178	604	−248
	−108	−75	−32	−3	−15	−30	−40	−9	−20	−45	−19	−30	−426		
1896	+52	+117	+4	+45	+49	+20	+16	+18	+1	+10	+27	+56	+415	712	+118
	−7	−2	−42	−24	−18	−5	−9	−6	−45	−32	−100	−7	−297		
1897	+6	+28	+35	+12	+24	+5	+15	+15	+64	+49	+18	+7	+278	527	+29
	−20	−8	−60	−9	−30	−22	−17	−18	−3	−8	−24	−30	−249		
1898	+39	+77	+45	+18	+14	+20	+14	+19	+21	+7	+2	+2	+278	568	−12
	−35	−8	−33	−28	−24	−4	−9	−5	−6	−42	−36	−60	−290		
1899	+22	+1	+1	+16	+20	+12	+4	+30	+16	+30	+110	+6	+269	724	−186
	−6	−140	−140	−24	−30	−13	−14	−26	−14	−12	−1	−25	−455		

TABLE I.—THE TEMPERATURE DEPARTURES FOR THE UNITED STATES, 1873–1909—*Concluded.*

Year	Jan.	Feb.	Mch.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Sums	Diff.
1900	+108	+9	+33	+48	+54	+42	+8	+38	+28	+75	+30	+59	+532	716	+348
	−2	−42	−30	−23	−1	−9	−13	−20	−15	−3	−24	−2	−184		
1901	+62	+7	+40	+12	+32	+25	+75	+21	+6	+23	+30	+12	+345	567	+123
	−1	−49	−14	−35	−19	−23	−2	−5	−14	−4	−20	−36	−222		
1902	+48	+40	+63	+19	+42	+12	+7	+17	+2	+30	+64	+7	+351	615	+87
	−12	−45	−12	−13	−5	−22	−19	−13	−46	−2	−5	−70	−264		
1903	+50	+12	+45	+9	+10	+14	+8	+7	+1	+30	+14	+18	+213	594	−168
	−3	−98	−15	−17	−28	−47	−25	−20	−45	−10	−22	−56	−381		
1904	+18	+40	+45	+10	+12	+3	+1	+5	+20	+20	+48	+12	+234	536	−68
	−40	−55	−9	−40	−13	−32	−30	−25	−9	−9	−10	−30	−302		
1905	+15	+10	+135	+12	+13	+11	+9	+20	+40	+5	+38	+12	+320	646	−6
	−56	−70	−1	−25	−30	−23	−30	−7	−1	−37	−8	−38	−326		
1906	+90	+60	+1	+42	+4	+8	+30	+20	+50	+17	+17	+55	+394	633	+155
	−2	−8	−90	−5	−12	−30	−24	−12	−3	−25	−12	−16	−239		
1907	+66	+72	+90	+7	+5	+4	+12	+13	+19	+45	+32	+80	+445	841	+49
	−80	−23	−7	−63	−85	−45	−15	−30	−17	−18	−13	0	−396		
1908	+100	+48	+80	+50	+9	+7	+20	+4	+50	+16	+52	+30	+466	658	+274
	−1	−20	0	−2	−36	−42	−17	−19	−6	−24	−5	−20	−192		
1909	+48	+64	+18	+6	+1	+10	+9	+28	+15	+12	+90	+2	+303	581	+25
	−16	−4	−18	−35	−36	−4	−24	−6	−10	−16	−1	−108	−278		

Mean temperature amplitude number 629

(3) These charts, in a more restricted problem, enable us immediately to test the phenomenon of the inversion of temperatures in the United States relative to that in the tropics, and to the variation of solar energy, whereby the force function of the circulation in controlling the local temperatures of the temperate zones can be fully realized.

It is necessary to integrate in a simple way the total effect of the temperature variations in the United States, by months and by years. We may conceive the temperature charts to represent cones, or topographical volumes of departures, and the volume for each month may be taken approximately,

$$\frac{1}{3} \text{ A} \, . \, d_{\max}$$

where A is the area of the region covered by a departure of one sign, and $d_{\max}$ is the maximum temperature variation at the apex, or practically the altitude of the cone. Since we are now seeking only relative numbers, the factor $\frac{1}{3}$ can be dispensed with as pertaining merely to the scale of the diagrams to be drawn, which is an indifferent matter. Thus, on fig. 1, take the area of the United States equal to 10; assume proportional parts for the positive and negative areas of departure, as 7 for the eastern or positive region, and 3 for the western or negative region; the positive maximum departure, not necessarily the highest station, is taken as 7 degrees, so that we have 7×7 = +49 to represent the strength of the positive temperature departures during the month, May, 1896, in the United States; the maximum negative departure for the western districts is about 6 degrees, so that 3 × (− 6) = − 18 represents the negative departure number for the same month; the sum of these without signs, 49 + 18 = 67, is the total average *amplitude*, that is the amount by which the temperature system departed from the normal in a series of high and low waves; the sum of these numbers with signs, +49 − 18 = +31, gives the average temperature *excess* for the United States, showing that this region averaged warmer than the normal for the month. Similarly, the numbers in Table I represent the relative changes in temperature for the United States month by month for 37 years, 1873 to 1909, inclusive. It can be seen by an inspection of Table I, that:

FIG. 1.

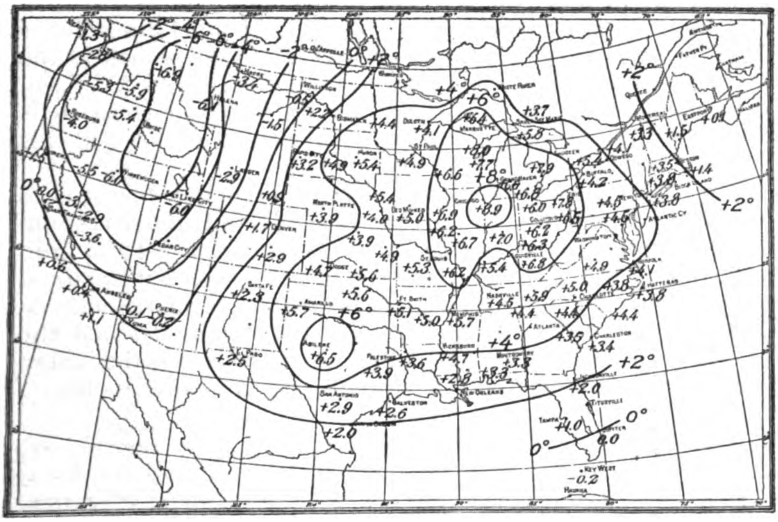

FIG. 1. Temperature Departures, May, 1896.
481 similar charts have been drawn, giving the temperature variations in the United States from January, 1873, to December, 1909.

(1) It is not possible always to treat the United States as a temperature unit in the midst of the world-departure (Newcomb), because there are many months when, as May 6, 1896, this region is not all warmer, or all colder, than the normal. There is a tendency for the temperature to oscillate about a sort of nodal line on the eastern edge of the Rocky Mountain Plateau; it sometimes happens that the interior of the United

States is of one departure sign, while the Coast States, Atlantic, Gulf of Mexico, Pacific, in whole or in part, are of the opposite sign.

(2) The strength of the *amplitudes* in winter is about twice as great, sometimes three times as great, as in the summer. In the winter the sun and the warm zones withdraw to the south, and the cold polar air moves southward. The strength of amplitude means that alternately warm and cold areas of air, warm cyclonic streams from the south, and cold anticyclonic streams from the north, pass over the United States in a turbulent circulation, the crests and hollows further apart in some years than in others. If the mean amplitude is 629, then the range in amplitude is from 426 in 1874 to 842 in 1878, or 1907, or 66 per cent for the entire series. In some months the maximum temperature departure is between 20° and 25° F., in other months only 2° or 3° F. The fundamental question is whether these variations are purely accidental or not, and this will be taken up in the following section.

(3) The *excesses* of temperature for the United States as a whole are shown in the last column of Table I, the maximum relative number being +470 in 1878 and −399 in 1875, indicating that during some years the temperature is maintained above the normal or average, and below the normal in others. The important point is to correlate the amplitudes and the excesses with solar phenomena in order to learn whether there is synchronism annually or not, and if any to classify its laws.

Synchronism between the variations in the numbers representing the frequency of the solar prominences, the sun-spots, the European terrestrial magnetic field, and the amplitudes or excesses of the temperature departures in the United States.

The curves representing these *frequency numbers* are brought together in fig. 2. The curve of solar prominences is plotted from Table 2, this Journal, May, 1908, p. 417: that for the European magnetic field is from Table 3, same paper; that for the sun-spot numbers is from Wolfer's frequency numbers; that for the temperature amplitudes is from the 15th column of Table 1 of this paper; and that for the temperature excesses is from the last column of the same table. I have not had an opportunity to extend the first two curves, of the prominences and the magnetic field, beyond the year 1905, as should be done. These curves are derived from relative numbers, and they are plotted on independent scales. The heavy mean line represents the consecutive *means* of the long-period, while the variations between this line and the original curve give the short-period *residuals*. It should be carefully noted that the curves of the temperature amplitudes and excesses are plotted inversely to the three other curves.

The synchronism in the long period between the two solar curves and three terrestrial curves cannot be questioned, that for the magnetic field being direct, and those for the temperature system of the United States being inverse. This result confirms the data and conclusions of my papers of 1894, 1898, 1903, mentioned above. The synchronism between the curves of short period is not so well pronounced as for the long period, and that for several reasons. The prominences and the magnetic curve are only approximate measures of the true solar radiation output, for which they stand as substitutes. We have no long-continued series of homogeneous radiation observations from which to construct a curve representing the gram calorics

FIG. 2.

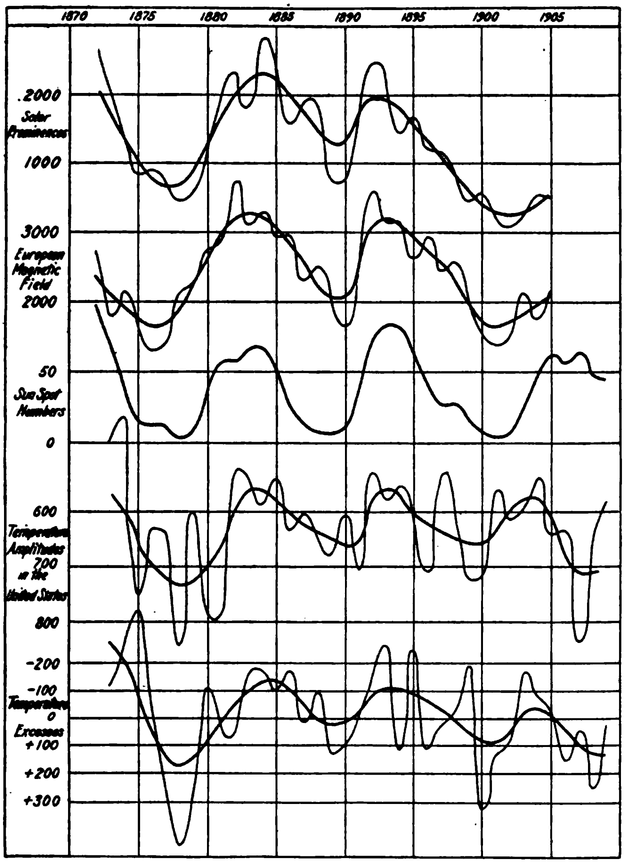

FIG. 2. Prominences, magnetic field, sun-spots and the temperature amplitudes and excesses in the United States.

per square centimeter per minute, that is the actual energy of the incoming solar radiation, and we must for some years be content with the available data. The solar prominence numbers are from the Italian spectroscopic observations on the edge of the solar disk, and these are only rough records of the total action of the solar mass as an emitter of radiant energy. Furthermore, the prominences break out earlier in the middle latitudes than near the equator or the poles, so that the general summation of prominence numbers obscures the times of free efficient emission to the earth. It is evident that systematic spectroheliograph observations of the face of the sun should be made in favorable climates, and the records should be carefully studied for the variations of the emission of solar energy by months and by years. The European magnetic field is represented by the mean horizontal force variations at a few stations, three to five, whereas the mean magnetic variation should be computed for all three components at about 10 stations for the entire earth. It is proper to infer that the precise synchronism shown between the prominences, sun-spots, and magnetic field in the long period can be extended to the short period by the expenditure of sufficient well-directed labor. The temperature curves match the short-period variations of the solar curves approximately, that is enough to recognize the same sequence of crests for each. We have shown that the temperature data is in itself of the highest order. On the other hand, it suffers from considerable unsteadiness as regards its synchronism with the solar energy on account of the inversion effects produced by the atmospheric circulation. The variations of temperature are direct with the solar energy in the Tropics, but inverse in the temperate zones. It follows that the high pressure belt is the node of this temperature effect, where the variation is indifferent. Since this belt is due to the circulation, and since the location of the belt in the United States is loosely defined, it is evident that some uncertainty in the temperature amplitudes and excesses must be expected. This high pressure belt usually runs from the Florida peninsula to northern California, but it is much broken up by the anticyclonic and cyclonic circulation through which the air from the Tropics mixes with that from the temperate zone.

It is easy to see that if these several curves could be suitably perfected, it would not be difficult to assert that certain coming years would be prospectively warmer or colder than usual. The years of maximum solar energy are years of minimum temperature and minimum amplitude. An increase of energy from the sun on the Tropics brings down colder air in the temperate zone and holds it more firmly at the surface of the earth, and the cold high areas are in excess, the winter and summer being cooler. The minimum solar action is followed by warmer seasons in the United States, a greater amplitude in the circulation of the warm and cold areas, and a more pronounced system of warm leakage currents from the Gulf of Mexico upon the Mississippi Valley. It is, also, seen that the succession of minor crests is usually about three years, this being the 3-year period first described by Bigelow in 1894.

FIG. 3.

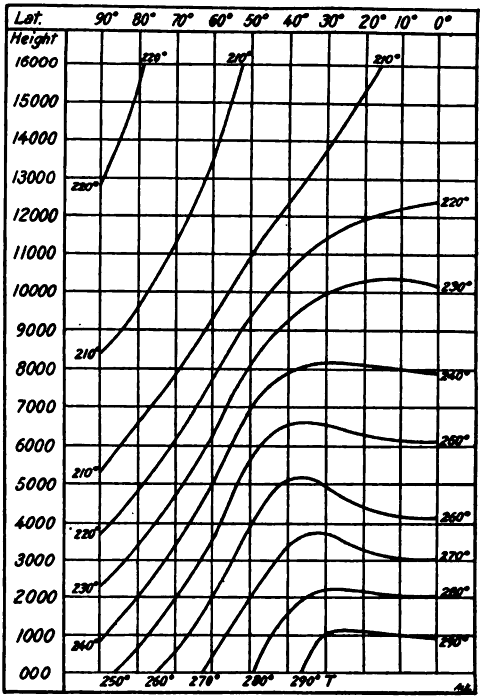

FIG. 3. The location of the mean annual isotherms in the earth's atmosphere.

The Cause of the Inversion of Temperatures.

In order that the cause of this important inversion of temperatures in the United States may be better understood, I will produce from my other unpublished studies on the General Circulation a diagram of the distribution of the mean annual temperatures in the atmosphere, as derived from balloon and kite ascensions, and from a study of the equations of motion. The vertical scale of the drawing is greatly magnified in fig. 3, in order to bring out the fundamental facts.

Imagine the quadrant of the earth's atmosphere between the equator and the poles to be rolled out into straight lines, and to extend from the surface to 16,000 meters in altitude. Then, the annual mean isotherms are disposed as indicated, subject to modification in details owing to the present lack of data, especially in the Tropics and the polar zones. The following facts should be noted: (1) In the lower levels the maximum temperature is at a higher altitude in latitude 30° to 40° than to the north or south of it; (2) the general depression of temperatures in the Tropics is due to the ascending circulation and adiabatic cooling; (3) the circulation in the Tropics is westward, because the isotherms rise upwards in going north and parallel to the earth's axis; (4) the circulation in the temperate zone is eastward for the opposite reason (see paper, Monthly Weather Review, January, 1904); (5) the rate of circulation depends upon the density of the isotherms in a line parallel to the earth's axis; (6) it is a maximum westward at the elevation 3000 to 4000 meters in the Tropics decreasing downwards and upwards, and reversing to eastward at about 10,000 meters (M. W. Review, April, 1904); (7) it increases upwards in the eastward drift of the temperate zones to about 12,000 meters and then falls off, as first shown in the International Cloud Report, 1898; (8) the chief function of the westward drift in the Tropics is to counteract by its motion the adiabatic cooling of the ascending air; (9) the chief function of the eastward drift is by its motion to hold the heated air of the tropic zone away from the polar region; (10) the small polar overflow in the upper levels is restricted to latitudes 50° or 60° by this circulation; (11) there is no pronounced upper poleward current and no well-defined lower equatorward current, with a neutral plane separating them, as Ferrel assumed in his canal theory; (12) the leakage currents from the Tropics to the temperate zones may occur in all levels, and then the centers of action and the wandering cyclones and anticyclones are formed; (13) the momenta of motion are continuously being readjusted between temperature and circulation to keep their sum a constant, and the angular rotation of the earth on its axis a constant; (14) in case the solar energy raises the temperature of the Tropics, with its westward drift, it follows that in the temperate zones there is an increase of eastward drift, a downflow of air, an increase of cold areas, and a decrease of amplitudes and the leakage currents; (15) an inversion of temperature in the temperate zone is a necessary result of this circulation, to balance an increase of temperature in the Tropics from the solar radiation energy. This, then, accounts for the many discrepancies which have been announced by investigators when comparing station records directly with the sun-spot numbers. It must be fully admitted that meteorologists have an exceedingly complex problem before them, but in view of the valuable results to be derived from a correct forecast of seasonal weather conditions, they will be justified in pursuing these studies to a practical conclusion.

Observations on the Solar Radiation and their Interpretation.

It will be seen from the foregoing statement of the several lines of correlated phenomena that the continuous record of the solar radiation is the missing link in the chain. The prominences and the sun-spots are products of the outgoing radiant energy and the accompanying solar circulation; the magnetic field variations are one result of the absorption of the incoming radiation in the earth's atmosphere, and the temperature changes are another product of it, linked up with the circulation, and thence with the barometric pressure and weather conditions generally. The study of the entire series of observational problems is greatly hindered at every turn by the instrumental expense of securing the necessary original observations, and the complicated results to be interpreted. It constitutes the greatest world problem for future generations to more perfectly work up and utilize. At present the magnetic field, all things considered, is the most suitable for the practical foundation. We have numerous magnetic observatories in all parts of the world, and the observations are easily secured. The magnetic variations are direct products of the incoming radiation through the process of ionization and electric currents, but there is a regional assorting going on in the earth's atmosphere, part of the incoming energy being transformed in the outer, thin, dry layers, and another part in the lower, dense, moist layers of the earth's atmosphere. Certain corpuscles and cathode rays may have special, irregular operations in the outer layers to produce spasmodic magnetic storms, but it is the transformation of energy in the lower layers that are chiefly concerned with the diurnal and the annual periodic variations of the magnetic field. We have only to interpret these in terms of solar radiation and terrestrial circulation to connect up the two branches of this subject.

The direct observations on the incoming solar radiation, by means of the bolometer readings on the individual rays of the spectrum, and the pyrheliometer on the total or integrated heat energy, are beset with unusual difficulties, partly instrumental and partly meteorological. The splendid progress made by the Smithsonian Astrophysical Observatory in developing a reliable instrumental equipment makes us hopeful of a practical result in respect to the observations. The meteorological problem, depending upon the temporary constituents of the atmosphere, is a subject of much perplexity. To illustrate the point we refer to fig. 4. Draw the black body curves of radiation for 7000° T and for 6000° T, by the Wien-Planck formula; lay down the curve of bolometer observations for a high mountain, as Mt. Whitney (Abbot) or Mt. Wilson (Abbot), in I, and for sea level, as Washington (Langley-Abbot), II. Abbot reports that his recent high and low altitude observations on the same day agree for the three level observations at Washington, Mt. Wilson, Mt. Whitney in producing a *total* amount of solar radiant energy equal to

FIG. 4.

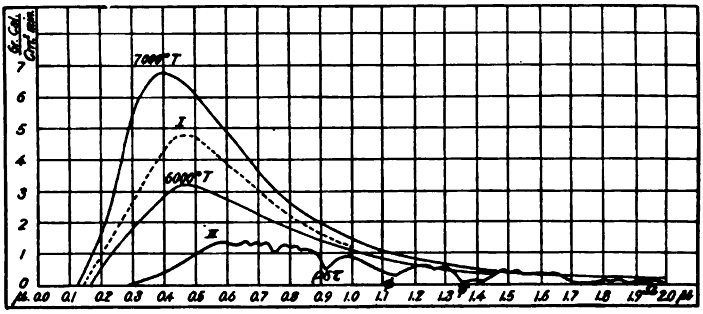

FIG. 4.—Black body radiation at 7000° T and 6000° T. Observed radiation on a high mountain (I) and at sea level (II).

about 1·92 gram calories per cm^2 per minute on the outermost layer of the earth's atmosphere. The depletion of the incoming radiation is chiefly by scattering, and it is progressive with the depth, the density and the impurity of the atmosphere, as determined by the dust, ice, and vapor contents, with the atoms and molecules of the gases themselves. In a word, the short waves are most heavily depleted and that progressively with the length of path, cutting off the apex of the pure energy curve in an irregular manner, so that it is very difficult to find the value of the maximum wave length from the observations, which we wish to introduce in the general formula,

$$T \, . \, \lambda_{\text{max}} = \text{Constant},$$

so as fully to determine the temperature of the radiating black body, responsible for the energy reaching the earth on a given date. Unless the crest of the radiation curve is found accurately, it will not be possible to assign any definitive temperature to the solar envelope with enough precision to enter into competition with the curves of fig. 2, in the forecast of weather conditions. Furthermore, the evidence of the observations seems to be at present, that the incoming radiation does not fit the ordinates of the black body at any one temperature. The wave lengths of the bolometer curve above 1·0 μ seem to require by their greater length a solar temperature of about 7500° T, while the wave lengths of the curve from 0·00 μ to 1·00 μ seem to be satisfied with something like 6500° T. If the sun is not radiating as a pure black body, as is very likely to be the fact, it follows that the study of the solar energy of radiation is an excessively complex problem. There is evidence from the prominences that the sun has an excess of energy along one diameter and a defect along the other at right angles to it; also, from the magnetic field that the areas of heat in solar longitude, while very irregular like incipient oceans and continents, are yet capable of classification; and, from the spectroscope that the great variations in the angular velocities at the photosphere, as 26·7 days at the equator to 31·0 days at the poles, or 26·0 near the level of the upper chromosphere over the equator to 29·0 days at the poles. These point to great changes in the local solar mass temperatures from place to place, though they may be deep seated. Such variations of the heat of the radiation energy at the sun, and of the absorbing and depleting capacities of the earth's atmosphere, render the problem of direct radiation measures one of exceptional difficulty. On the other hand, we have in the earth's magnetic field one of the most sensitive, natural instruments for registering the effects of solar radiant energy, which will be utilized before long in its highest functions. If ionization is a direct product of radiation, and it is registered accurately though indirectly in the magnetic field, it follows that this is our easiest approach to a working method of handling the materials in questions. It will doubtless require much more labor to remove some of the barriers that still stand in our way. The simple or superficial application of the standard formulas of radiation to the temperature indicated in fig. 3, will show how far we are from accounting for this distribution by any of the elementary methods heretofore discussed. It is necessary to separate the circulation effects from the radiation effects, and to separate the incoming radiation effects from the outgoing radiating effects. As none of these steps have yet been taken, we may consider the subject of the relations between radiation, temperature and circulation as virgin ground for an extensive research.

It is well to note the growth of interest and conviction in the minds of students regarding the practical validity of this solar-terrestrial problem. We have only to recall the numerous papers on the subject in recent years, besides those of the writer, by Langley, Abbot, Fowle, Lockyer, Clayton, Clough, Artowski, Merecki, and the several International Commissions on Solar Physics and Meteorology.

U. S. Weather Bureau, Washington, D. C.

ART. IX.—*The Effect of the Presence of Alkalies in Beryl upon its Optical Properties;* by W. E. FORD.

THE attention of the writer was called to the subject of the effect of the presence of alkalies in beryl upon its optical properties by a note in an article by Lacroix* on the tourmaline-bearing pegmatite veins of Madagascar. A description is given there of a rose-colored beryl which possessed unusually high values for its indices of refraction and specific gravity, and which on qualitative examination showed the presence of alkalies, notably cæsium. The assumption naturally followed that these abnormal values for the refractive indices and specific gravity were due to the presence of the alkalies in the mineral. This seemed a point of sufficient interest and importance to merit further investigation.

The rôle played by the alkalies in beryl was determined in this laboratory, a number of years ago, through a series of analyses by Penfield,† and later by the same investigator and Sperry.‡ Specimens of the beryls rich in alkalies upon which these analyses were made are preserved in the Brush collection, and in two cases yielded material suitable for optical investigation. It was possible to make an orientated prism and to measure the indices of refraction of the beryl from Willimantic, Conn., analyzed by Penfield,‡ and also of the cæsium beryl from Hebron, Maine, analyzed first by Penfield,† and then later by Wells.§ In addition to these, two other beryls were investigated, first the pink beryl from San Diego Co., California, in which the writer determined qualitatively some years ago the presence of alkalies,‖ and second, the rose beryl from Madagascar, presumably the same as described by Lacroix. Specimens of the Madagascar beryl of gem quality were generously placed at the writer's disposal by Dr. G. F. Kunz.

An analysis was first made of the pink beryl from Mesa Grande, San Diego Co., California, the material being furnished by an irregular fragment of gem quality which was presented to the Brush collection by Mr. E. Schernikow. The analysis showed a total of 1·48 per cent of alkali oxides, a smaller amount than had been anticipated and, further, gave no test for the presence of cæsium. As the specimen analyzed showed no crystal faces it was impossible to cut an orientated prism from it by means of which the two indices of refraction could be determined. A prism was, however, cut at random from a fragment of the material and the value of the index for the ordinary ray obtained. There was in the Brush collection a small crystal group of faintly pink beryl from the neighboring locality of Pala and, thinking, that from this specimen both indices might be determined, an orientated prism was cut from it and measurements of the two indices made. The values of the indices for the ordinary rays as determined from the two prisms were, however, quite different, that of the Pala beryl being the higher. This suggested that the two specimens differed in the amount of the alkali oxides which they contained and this was proven by sacrificing enough of the crystal to permit the making of a determination of the alkalies present. The Pala beryl was found to contain 3·77 per cent of alkali oxides of which over half of a per cent proved to be cæsium oxide.

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* Bull. Soc. Min., xxxi, 218, 1908. † This Journal, xxviii, 25, 1884.
‡ Ibid, xxxvi, 317, 1888. § Dana's System of Mineralogy, 6th ed., p. 407.
‖ This Journal, xxii, 22, 217, 1906.

The rose-colored beryl from Madagascar contained still more alkalies, 4·98 per cent in all, 1·60 per cent of which was cæsium oxide. The material analyzed showed no crystal faces and the prism for the measurement of the indices of refraction, also, had to be cut at random. It happened, however, that it must have been cut with its edge very closely parallel to the direction of the optical axis for the birefringence shown was quite what would have been expected through the study of the various other results. In order to prove the orientation of the prism, a section was cut from it at right angles to its faces and, in convergent light, this section showed an unaxial interference figure nearly symmetrically centered in the field of conoscope. So the

	I Mesa Grande Analyst, Ford	II Willimantic Analyst, Penfield	III Pala Analyst, Ford	IV Madagascar Analyst, Ford	V Hebron Analyst, Wells
SiO_2 ...	64·98	65·72	undet.	62·79	62·44
Al_2O_3 ..	17·86	18·40	undet.	17·73	17·74
Fe_2O_3 ..	----	----	----	----	0·40
FeO ...	----	0·26	----	----	----
MnO ...	----	0·12	----	trace	----
BeO ...	13·42	13·08	undet.	11·43	11·36
Cs_2O ...	----	----	0·57	1·70	3·60
K_2O....	0·18	0·12	0·28	----	----
Na_2O ..	0·84	0·75	1·59	1·60	1·13
Li_2O ...	0·46	0·28	1·33	1·68	1·60
Ign	2·16	2·06	undet.	2·65	2·03
Total ..	99·90	100·79	----	99·58	100·30
Total alkalies	1·48	1·15	3·77	4·98	6·33
Specific gravity	2·714	2·73	2·785	2·79	2·80
ω =	1·58157	1·58455	1·59239	1·59500	1·59824
ϵ =	undet.	1·57835	1·58488	(1·58691)*	1·59014
$\omega-\epsilon$=		·00620	·00751	(·00809)*	·00810

* Approximate.

values of the index for the extraordinary ray and the birefringence, as determined from the prism, while not exactly correct, must be very nearly so and consequently they have been quoted, the figures being enclosed in each case in a parenthesis.

Above are given the various analyses with the corresponding determinations of the indices of refraction and specific gravity. The indices of refraction were all measured in sodium light.

From the consideration of the above table it is quite clear that the replacement of beryllium oxide in beryl by the various alkali oxides raises both the specific gravity and the values for the indices of refraction in the mineral. There is also shown an increase in the amount of birefringence as the percentage of the alkali oxides rises. The relationship that exists in minerals between their composition and their optical constants is at best exceedingly complicated. And in the case of beryl where one oxide (BeO) is replaced in varying amounts by four other oxides (Li_2O, Na_2O, K_2O, and Cs_2O), possessing widely differing molecular weights, it is impossible in our present state of knowledge to derive any law that shall accurately coördinate the chemical and optical factors. It is, however, a recognized fact that, in general, where a mineral varies in its composition by the isomorphous replacement of one element or oxide by another, the values of the indices of refraction and the specific gravity are raised, when the replacing element or oxide has a higher atomic or molecular weight than the one replaced and vice versa. The results of the present investigation of beryl are fully in accord with this principle. The effect of such variation in composition upon the birefringence of the mineral is, however, apparently not necessarily a corresponding one, although, in the case of beryl, it also rises in amount with increase in the values of the indices of refraction.

An interesting fact might be noticed in this connection. Ordinarily because of their comparative low molecular weights (excepting in the case of the rare oxide of cæsium) the introduction of alkali oxides into a mineral serves to lower its indices of refraction and birefringence. The opposite is true in beryl and apparently so because the oxide replaced, BeO, has a lower molecular weight than any of the alkali oxides, the respective values being as follows: BeO, 25·1; Li_2O, 30·06; Na_2O, 62·10; K_2O, 94·30; Cs_2O, 281·76. It could, therefore, be reasonably assumed that the introduction of any of the alkalies would cause the rise of the values for the refractive indices, but it is probable, however, that the presence of cæsium oxide with its high molecular weight would have the predominating influence.

Laboratory of Mineralogy,
Sheffield Scientific School, Yale University,
New Haven, Conn., June, 1910.

ART. X.—*The Correlation of the Guadalupian and the Kansas Sections**; by J. W. BEEDE.†

Introduction.—The appearance of the "Guadalupian Fauna"‡ again brought into prominence the question concerning the age of the rocks of Kansas and Oklahoma that have usually been referred to the lower Permian. The writer thought it quite necessary to make a trip to the Guadalupe region last season in order to determine anew the stratigraphic relationship and, if possible, to determine the paleontologic interrelations of the red beds and the Guadalupian limestones. These red beds are common to the Texas and Kansas regions, and their age and relationships are known. If the relative position of these beds to the Guadalupian deposits could be established, then the correlation of the deposits with those of Kansas could readily be made. The outcrop of the Guadalupian strata were therefore studied during the summer of 1909, and with the assistance of Mr. Hal P. Bybee during the earlier part of the season.

Stratigraphy.

Our visit to the region last summer was for the purpose of reviewing the stratigraphic relationship and determining whether the Pecos valley red beds actually occupied a higher position than the Guadalupian limestones and, if possible, to secure fossils from them which would demonstrate their age. Only the general itinerary and more important observations will be mentioned here.

After a brief survey of the region lying east of the Davis mountains, from Phantom Lake to Kent, and San Martine, Texas, we traveled west and north from Toyah over the Cretaceous red beds, and along the eastern outcrop of the Delaware mountain formation to Guadalupe Point. Here the upper part of the type section of the Guadalupian series was studied and collections made. Then at Carlsbad, New Mexico, the Pecos valley red beds with the subjacent limestones and sandstone were seen, with broad, low anticlines of the upper Guadalupian limestone protruding through them. Farther west the gypsum deposits of the red beds appeared in the synclines and on the sides of the anticlines. East of Queen the upper-Guadalupian limestones rise from beneath the gypsum beds and form the mass of the Guadalupe mountains of this region, some thirty miles north of Guadalupe Point. A trip south through the mountains to the Texas line gave assurance of the stratigraphic position of the uppermost beds shown at Carlsbad and at Queen.

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* Read before the Paleontological Society of America, Dec., 1909.

† By permission of the State Geologist of Kansas.

‡ Girty, U. S. Geol. Surv., Prof. Paper 58, 1908 [1909]. See also Richardson's paper in this Journal, April, 1910, pp. 325-337.

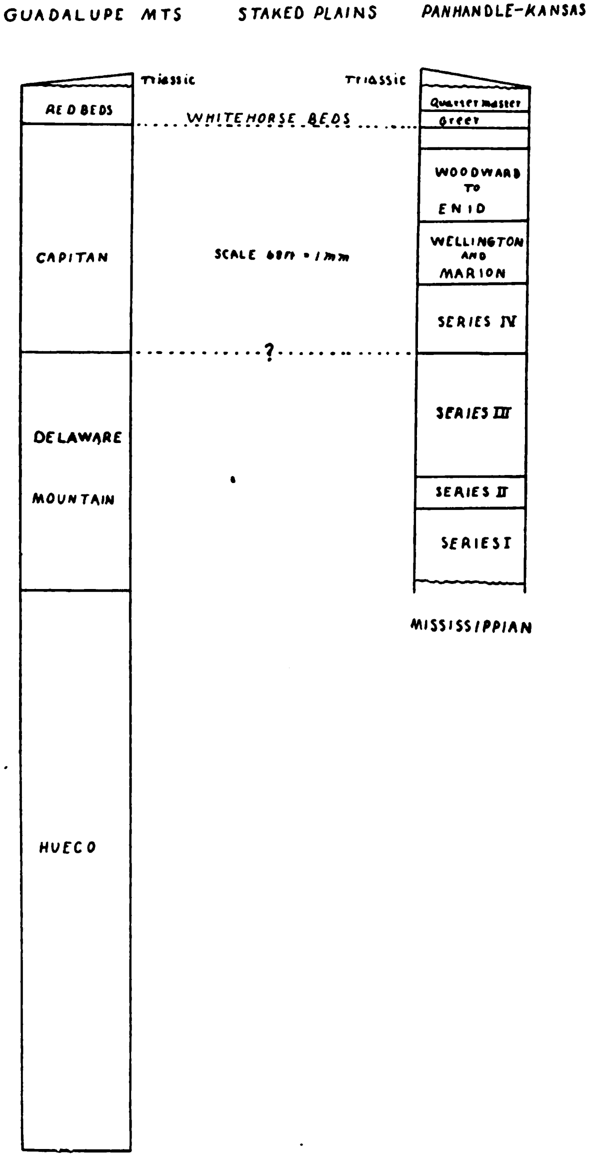
Near Carlsbad were studied a locality thirteen miles west of town (five miles west of McKitrick spring), and another at the mouth of Dark canyon. The beds here consist of thin limestones and covered slopes apparently composed of soft sandstones or clays. Shales are visible at McKitrick spring. These rocks overlie the massive upper Guadalupian limestone. Numerous pieces of yellowish sandstone were seen on the north side of Pine canyon, near Guadalupe Point on the top of the mountain, though none were seen in place. Near the head of Dog canyon and about Queen the sandstones are in place. The stratigraphy is well shown in Sitting Bull canyon just below Queen. The physical character of the Capitan in the northern extension of the Guadalupes changes rapidly. In Pine canyon itself it seems to be composed to some extent of large lenticular masses, while in Sitting Bull canyon rocks nearly 500 feet below the summits of the mountain show cross-bedding on a magnificent scale. Sometimes the lithological character of the beds varies very rapidly. North of the region of Guadalupe Point, the purer limestones appear to be replaced by those of dolomitic appearance, and with this change the Capitan fauna ceases, being nearly unknown north of the Texas line.

In the vicinity of Carlsbad the general stratigraphic relations of the red beds and underlying limestones and sandstones are well shown. A section of the rocks at the locality west of the McKitrick spring is as follows:

10.	First terrace of thin-bedded limestone resting on Guadalupian limestone	70	ft.
9.	Main cliff of limestone	70	"
8.	Soft arenaceous limestone	5	"
7.	Limestone lying below main cliff	12	"
6.	Limestone, pisolitic in the upper part	5	"
5.	Limestone, hard, oolitic in places	15	"
4.	Hard limestone, locally oolitic	5	"
3.	Limestone, dark below, lighter above	50	"
2.	Dense or porous limestone with much travertine	4	"
1.	Fine-grained crystalline homogeneous limestone	5	"
	Total	241	"

Fossils were taken from blocks of massive limestone, probably from near the base of the section. Near Carlsbad these upper rocks (number 10 of the section), and other strata not exposed, appear to be two or three hundred feet thick and plunge with gentle dip beneath the red beds of the Pecos valley. The red beds of this region are composed of sand-

Fig. 1.



stones, clays, and bands of limestone separating gypsum beds. The western extension of the beds is nearly void of red sandstones and clays and only thin bands of limestone occur with just sufficient red material to suggest their relationship to the rocks a few miles farther east, where the clays and sands are more abundant. However, about ten miles northwest of San Martine is an outcrop of a hundred feet or so of red sandstone which may possibly be Triassic in age.

East of Carlsbad, near the rim of the Staked Plains, red sandstone overlies the gypsiferous beds. These beds were reported to me by Professor E. O. Wooton, of the Agricultural college at Las Cruces, who made a trip up to the Plains at the time of my visit. They are the Triassic beds of Drake.*

The gypsiferous beds are excellently exposed in the high bluff six miles south of Lakewood, south of the South Fork of Seven Rivers and west of the Pecos river. In the northern scarp of the hills, near the eastern end, the gypsum is nearly 300 feet thick as measured by the barometer. The layers are separated by thin bands of limestone. Red materials appear on the eastern and western extension of these hills near their base. There is a limestone above the gypsum beds varying from ten to seventeen feet in thickness, but which is much thinner a mile or two farther west in the same hills. About ten feet below the crest of the escarpment and a little west of its eastern end, fossils were found, some of which are like those occurring in the Quartermaster beds in the Texas Panhandle.

On the east of the Pecos river two miles southeast of the mouth of the South Fork of the Seven Rivers, Fisher finds the following section :†

Massive gray limestone	35 ft.
Gypsum and red sandstone in alternating layers with occasional limestone ledge	50 "
Gypsum with thin-bedded, porous limestone, and red sandstone arranged alternately, the gypsum predominating	150 "
Gypsum with thin layers of gray limestone	50 "
Total	285 "

This section exhibits the normal red beds conditions east of the Pecos river and should be compared with the others from east of the river given on the same page. Cummins has compared the lithologic character of these beds with the gypsiferous upper red beds east of the Staked Plains, as well as demonstrated their stratigraphic continuity.‡ For the sake of illustrating the similarity the following section taken at Kiowa peak, Stonewall County, Texas,* is given:

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* Geol. Surv. Tex., Third Ann. Rep., p. 246, 1892.

† U. S. Geol. Surv., Water Supply Paper 158, page 7, 1906.

‡ Geol. Surv. Tex., Third Ann. Rep., pp. 201–223, 1892.

1. Gypsum and clay	60 ft.
2. Red clay	20 "
3. Gypsum	20 "
4. Red clay	35 "
5. Gypsum	15 "
6. Gypsum, alabaster	4 "
Total	154 "

In this section the more minute details are omitted, and some thin limestones containing fossils are not given. It is doubtful if the whole thickness of the gypsum-bearing beds is seen since at the exposure the top of the hill is capped with massive gypsum. However, the succession of gypsum lentils. red clay and red sandstone is similar to that of the west side of the Pecos valley, as shown in Fisher's sections. Along much of their outcrop through the Panhandle, Oklahoma, and southward, the Greer formation, or the gypsiferous beds of the upper red beds, are overlain by a rather extensive layer of dolomite. It is found at Dozier, Texas, southwestern Oklahoma, and at Quanah, Texas. There is a similar covering of dolomite in many places in the western Pocos valley region.

Paleontology.

Since the stratigraphic evidence regarding the identity of the Pecos valley and the upper red beds east of the Staked Plains is so complete, it now remains to examine the meager paleontologic data at hand.

The fauna of the Whitehorse and Quartermaster beds has been described and its character noted.† The most common fossils of these beds are the pelecypods referred to the genus *Cyrtodontarca.* Indeed, scarcely a fragment of the fossiliferous stone can be picked up in which they are not abundant (I refer to the larger forms). These fossils are not so plentiful in any other horizon in this country so far as I am aware, and they may be considered the characteristic fossils of these beds. The Whitehorse and Quartermaster beds contain nearly forty species of fossils. The dolomites between these beds contain abundant *Schizodus* and *Pleurophorus* shells.

The fossils of the Pecos valley region are very rare so far as our present knowledge goes. Fisher found some in the limestone beneath the gypsum beds northwest of Roswell. He states that "Fossils are not abundant in the formation, but in one locality northwest of Roswell a number were collected, which consisted mainly of *Schizodus* and *Pleurophorus*, preserved as casts. According to Dr. Girty, the fauna and lithology of these specimens suggested the latest Carboniferous beds or Permian of the Mississippi valley in Texas." *

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*Cummins, Geology of N. W. Tex., Geol. Surv. Tex , Sec. Ann. Rep., p. 407, 1891.

†Beede, Invertebrate Paleontology of the Upper Permian Red Beds of Oklahoma and Panhandle of Texas, Kans. Univ. Sci., Bull. iv, pp. 115–168, 1907.

This correlation is in accord with the stratigraphic relationship of the beds, though Girty, in a later paper, discredits the evidence of *Pleurophorus*.

So far as I am aware this is the only record of fossils admitting of reasonable determination being found in the Permian red beds of the Pecos valley. At the locality south of Lakewood, previously described, in the limestone capping the gypsum escarpment at a horizon probably 300 feet or more above the horizon of Fisher's specimens, fossils of some five or six species were found. They consist of *Cyrtodontarca? parallellidentata?* † C.?sp., another pelecypod, the cast of an ostracod, and some minute gastropods from one to three millimeters in length badly preserved as molds. The *Cyrtodontarcæ* appear, though poorly preserved, to be specifically identical with one of the species from the Whitehorse and Quartermaster beds of Oklahoma and the Panhandle of Texas. Like them, these shells are by far the most abundant fossils in the collection.

At the locality west of Carlsbad, already described, in what seems to be the top of the Guadalupian limestone, specimens of *Naticella transversa*, formerly known only from the Quartermaster beds, and a *Pleurophorus* common to both the Whitehorse and Quartermaster formations, together with a few other poorly preserved specimens, were found. This occurrence indicates an earlier appearance of some of the Quartermaster forms in New Mexico than farther northeast.

These faunas of the Pecos valley red beds, limited as they are, seem to show nearly as intimate a relationship to those of the upper red beds east of the Staked Plains as does the stratigraphy of the deposits in which they occur. In short, there can be little doubt of the identity of the Pecos valley red beds with the Greer and adjacent formations of Oklahoma and western Texas.

After the Pecos valley and Guadalupe work had been completed, the writer and Dr. G. B. Richardson of the federal Survey, who had completed a similar reconnaissance in the Pecos valley and Guadalupe mountains and the region to the northwest, met at Carlsbad and compared results. His results are now published in the April number of this Journal.

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* Fisher, loc. cit., pp. 7, 8.

† Identical with a Quartermaster form doubtfully referred to this genus.

General Correlations.

If the conclusions reached above are correct it leads at once to the correlation of the Kansas and Guadalupian sections. If we use the Whitehorse sandstone, probably the equivalent of the beds in contact with the Guadalupian limestone near Carlsbad, as a common basis of correlation of the two sections, we attain the result shown in the accompanying diagram.

FIG. 2.

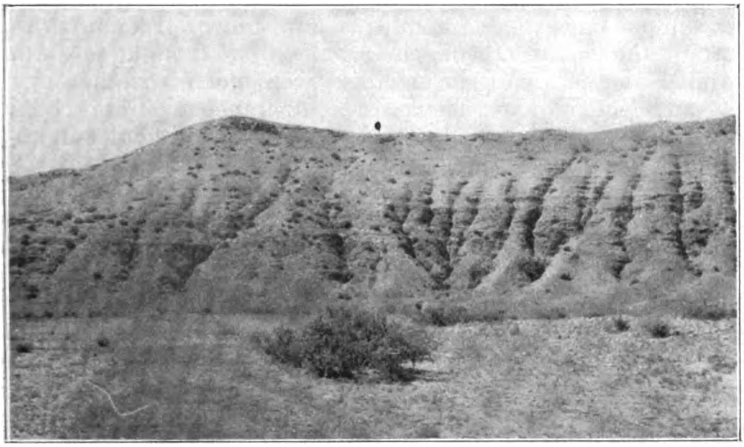

FIG. 2. Gypsum bluff six miles south of Lakewood, New Mexico. Fossils from near top of bluff just below the dark spot in the center of picture.

Disregarding their actual faunal relationships and comparing them as to their thickness, the strata of the two sections compare as follows, the figures of the Guadalupian rocks being approximations:

In southern New Mexico we have some 4,500 feet of the Guadalupian series composed of 2,100 feet of Capitan and overlying limestones and 2,400 feet of the Delaware Mountain formation composed of limestones and sandstones overlying 5,000 feet of Hueco limestones. Beginning at the same horizon in Kansas, we have the remainder of the red beds, the lighter Permian and the Pennsylvanian, aggregating about 4,500 feet of strata, composed of limestone shales and sandstone. So far as mere thickness is concerned it leaves the base of the Delaware Mountain formation about on the level with the base of the Cherokee shales (as exhibited in Kansas). The horizon of the base of the Delaware Mountain formation in the Kansas section interpreted upon its fauna, or actual time equivalency, may be a very different matter. The base of the Capitan falls near the bottom of the Elmdale formation stratigraphically, which is, probably, not far from its correct faunal correlation as well. The paleontological comparisons are yet to be worked out. The unconformity above the Capitan limestone and locally even on the Delaware Mountain formation, the Capitan having been carried away, is not taken into account in making these comparisons.* It is probable that it diminishes rapidly to the northward, where it is of less consequence.

One of the most interesting features of the Guadalupian fauna is its isolation. As has been stated by Girty, the fauna is a unique one, and, as a unit, is now known from no other part of the western hemisphere. At first thought it seems peculiar that more of its members were not distributed over the adjacent regions where contemporaneous strata occur. Their absence in such rocks has been a serious difficulty in any attempt to correlate them with other American faunas.

In the first place, the lower red beds lying to the eastward, with which the Guadalupian limestones are probably contemporaneous, are believed by some to be to a considerable extent of subaërial origin, while the temporary seas that occupied portions of it from time to time were too concentrated in salt content for normal marine faunas. So far as my collecting in the typical Capitan limestone goes, the fossils were abundant only in the purer limestones, and were very rare or wanting in what appeared to be the dolomitic portions of it. These limestones occur in the Apache Mountains and at Guadalupe Point, but appear to be wanting, as does the fauna, north of the Texas line; the only exceptions noted were *Fusulina elongata*, and one or two other species in Dog canyon and Sitting Bull canyon. From this it will be seen that the fauna was closed off on the north by untoward conditions and on the east by the red bed sedimentation, which constituted a barrier. No other barrier is known.

Two other considerations must be taken into account. First, that the Permian facies of this fauna may be an abnormally early precursor of the Permian faunas developed in an isolated basin.† Such an occurrence of Permian forms is known in Kansas well down in deposits of Pennsylvanian age. However, the variety and richness of the Guadalupian fauna, which possesses such a young appearance, seem to me to argue against this hypothesis. Second, the other possibility is that the fauna is no older than it appears and that it developed normally with little outside connection, as did the Kansas Permian fauna. The same features as before would have controlled its isolation. Much of the red beds being almost a land surface a considerable part of the time—if we accept the subaërial origin of a large part of the deposits—aggradation may have but slightly overbalanced degradation and they may have accumulated slowly for that class of sediments. Thus, though disturbances raised the southern part of the Guadalupe limestones above sea level and permitted their partial removal and the subsequent deposition of the upper red beds upon the eroded surface, the fauna may well have been an early Permian fauna. Until further data are at hand I am much inclined to this latter hypothesis. The fact that several hundred feet of the Kansas Permian deposits grade off into typical red beds in a very short distance in Oklahoma is suggestive of possible conditions east of the Guadalupes. If such were the case, we

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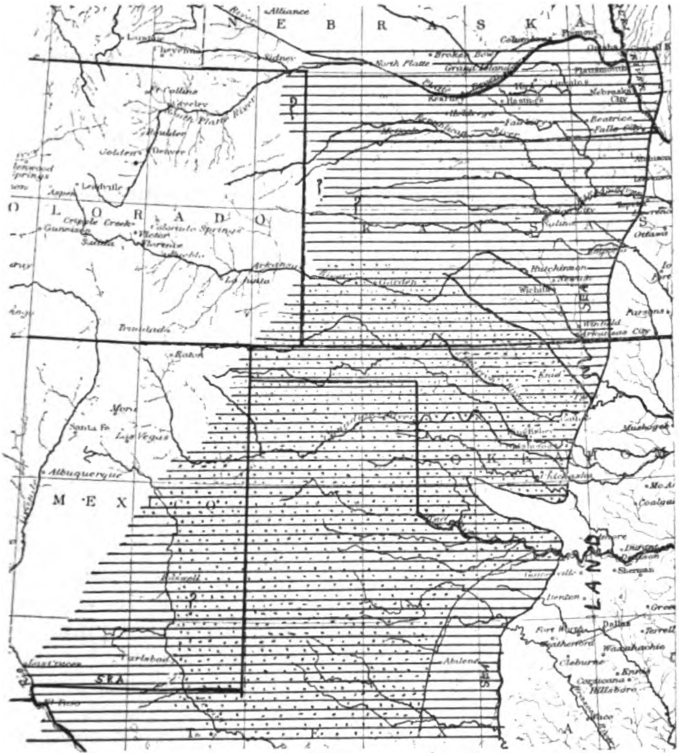
* Richardson, Univ. Min. Surv. Tex., Bull. 9, pp. 43–44, 1904.

† The idea of local isolation of the fauna was first suggested to me by David White and later, at the meeting of the Paleontological Society, by J. M. Clarke.

FIG. 3.



would expect the Guadalupian faunas to cease as abruptly upon the strata changing to the red beds as the Kansas faunas do upon entering the Oklahoma red beds.

At the same time, owing to the very nature of the origin of the red beds, their extreme southwestern part may have been deposited slightly later than the main mass farther to the north and east. However, this is regarded more in the nature of a possibility than a probability.

The accompanying map (fig. 3) indicates the probable relationship of the marine areas during Council Grove-Chase and Guadalupian time in the immediate area under consideration. No attempt is made to show the full extent of deposits laid down at this time. The full lines indicate marine conditions and the lines alternating with stippled ones continental-marine deposition. The extent to which the two factors contributed to the formation of the red beds is at present unknown. The area of marine conditions in Central Texas is to represent the Albany sea.

Bloomington, Indiana.

ART. XI.—*The Application of Potassium Ferricyanide in Alkaline Solution to the Estimation of Vanadium and Chromium;* by HOWARD E. PALMER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxiii.]

IN previous papers from this laboratory methods for the estimation of cerium in the presence of the other rare earths,* for the estimation of thallium,† and for the estimation of arsenic, antimony, and tin‡ have been described, based on the oxidizing action of potassium ferricyanide in alkaline solution, and reoxidation by permanganate of the resulting ferrocyanide in acid solution.

The present paper deals with the application of these reactions to the estimation of vanadium and chromium. The reactions involved may be represented by the following equations:

$$V_2O_4 + 2K_3FeC_6N_6 + 2KOH = V_2O_5 + 2K_4FeC_6N_6 + H_2O.$$
$$Cr_2O_3 + 6K_3FeC_6N_6 + 6KOH = 2CrO_3 + 6K_4FeC_6N_6 + 3H_2O.$$
$$5K_4FeC_6N_6 + KMnO_4 + 4H_2SO_4 = 5K_3FeC_6N_6 + 3K_2SO_4 + MnSO_4 + 4H_2O.$$

Estimation of Vanadium.

A solution of ammonium vanadate was made up by dissolving pure ammonium vanadate in water, and standardized by evaporating definite portions in a platinum crucible and weighing as V_2O_5 after ignition.

Through definite portions of the standardized solution of ammonium vanadate, made slightly acid with hydrochloric acid, a current of sulphur dioxide was passed until the clear blue color indicated complete reduction of the vanadium to the condition of V_2O_4. The solution was then boiled in a current of carbon dioxide until the last traces of sulphur dioxide were removed. To the cooled solution a solution of potassium ferricyanide containing at least ten times as much ferricyanide as is theoretically necessary for the oxidation, and a solution containing about 6 grams of potassium hydroxide were added, having the solutions of ferricyanide and potassium hydroxide sufficiently concentrated so that the total volume of the solution was about 100 or 125 cubic centimeters. At least the amounts of ferricyanide and potassium hydroxide stated were found to be necessary to ensure complete oxidation of the vanadium with the concentration employed, and if the solution was more dilute, more ferricyanide was required. It then became necessary to remove the vanadium before acidification and titration with permanganate, as, if not removed, it would form a precipitate with the ferrocyanide. The removal of the vanadium was effected by means of a solution of barium hydroxide, which completely precipitated the vanadium as barium vanadate; this precipitate, after settling, was filtered off on an asbestos felt, and the filtrate and washings were acidified with hydrochloric acid and titrated with permanganate. Titration in sulphuric acid solution was unsatisfactory on account of the difficulty in noting the end point in the presence of the precipitate of barium sulphate which was formed by the action of the sulphuric acid on the excess of the barium salt, and it has been found, in connection with the previous work, that, unlike the case of ferrous salts, ferrocyanide may safely be titrated by permanganate in the cold in dilute hydrochloric acid solution. The results of the determinations are recorded in Table I.

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* This Journal, xxvi, 83. † Ibid., xxvii, 379. ‡ Ibid., xxix, 399.

TABLE I.

	V_2O_5 taken grm.	$K_3FeC_6N_6$ used grm.	KOH used grm.	V_2O_5 found grm.	Error grm.
(1)	0·0960	4	6	0·0959	−0·0001
(2)	0·0960	4	6	0·0954	−0·0006
(3)	0·0960	4	6	0·0956	−0·0004
(4)	0·0960	4	6	0·0962	+0·0002
(5)	0·0960	4	6	0·0956	−0·0004
(6)	0·0960	4	6	0·0959	−0·0001
(7)	0·0960	4	6	0·0961	+0·0001
(8)	0·0960	4	6	0·0961	+0·0001
(9)	0·0960	4	6	0·0960	±0·0000
(10)	0·0960	4	6	0·0961	+0·0001

Estimation of Chromium.

As Bollenbach and Luchmann have recently shown,* chromium may be quantitatively oxidized from the condition of Cr_2O_3 to the condition of CrO_3 by potassium ferricyanide in alkaline solution, and a measure of the oxidation obtained by titrating with permanganate the ferrocyanide formed.

According to their method an excess of at least 4 to 6 times the theoretical amount of potassium ferricyanide and 40 to 50 cubic centimeters of a 2-normal solution of sodium hydroxide were added to the solution containing the chromium to insure complete oxidation of the chromium. The oxidized chromium was removed by precipitation as barium chromate by means of barium hydroxide solution, and filtration. The filtrate was then acidified with hydrochloric acid and titrated with permanganate according to Bollenbach's modification of De Haen's method,† designed to overcome the difficulty involved in obtaining an exact end point in the titration of large amounts of ferrocyanide, owing to the formation of a precipitate of $K_2MnFeC_6N_6$ during the titration, as was first pointed out by Grützner.* This modification consisted in adding an excess of permanganate to the solution and, after the precipitate had cleared up, titrating back the excess of permanganate with $\frac{n}{20}$ potassium ferrocyanide in the presence of a trace of a ferric salt, the formation of a permanent green coloration due to the ferric ferrocyanide indicating the end point.

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* Zeitschr. für anorg. Chem., lx, 446.

† Zeitschr. für anal. Chem., xlvii, 687.

In experiments carried on in confirmation of this method a solution of potassium chromate was used, whose standard had been determined by precipitating definite portions as mercurous chromate and weighing as Cr_2O_3 after ignition; and also by precipitating as chromium hydroxide by ammonia, after reduction with hydrochloric acid and alcohol, and weighing as Cr_2O_3.

The determinations were made as follows: Portions of the standardized solution were made slightly acid with hydrochloric acid, and a current of sulphur dioxide was passed through the solution until the clear green color indicated complete reduction of the chromium to the condition of Cr_2O_3. The sulphur dioxide was then expelled by boiling in a current of carbon dioxide. To the cooled solution potassium ferricyanide and potassium hydroxide were added in solution and the procedure given by Bollenbach and Luchmann, as outlined above, was followed.

However, using the amounts of ferricyanide and potassium hydroxide given by Bollenbach and Luchmann as sufficient to completely oxidize the chromium, the low results of Table II were obtained, indicating that the oxidation of the chromium was incomplete; but by using about 15 times the theoretical amount of potassium ferricyanide and a rather strong solution of potassium hydroxide, with the total volume of the solution about 100 or 125 cubic centimeters, as in the experiments recorded in Table III, results were obtained which were in accordance with the theoretical.

As in the previous work, a correction had to be applied to the determinations for the amount of permanganate taken up by the ferricyanide alone.

TABLE II.

	CrO_3 taken grm.	$K_3FeC_6N_6$ used grm.	KOH used grm.	CrO_3 found grm.	Error grm.
(1)	0·1010	6	12	0·0979	—0·0031
(2)	0·1010	8	16	0·0981	—0·0029
(3)	0·1010	8	16	0·0989	—0·0021
(4)	0·1010	8	12	0·0997	—0·0013

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* Chem. Zentralblatt, 1902, i, 500.

TABLE III.

	CrO_3 taken grm.	$K_3FeC_6N_6$ used grm.	KOH used grm.	CrO_3 found grm.	Error grm.
(1)	0·1010	16	15	0·1016	+0·0006
(2)	0·1010	16	15	0·1014	+0·0004
(3)	0·1010	16	15	0·1013	+0·0003
(4)	0·0505	16	15	0·1514	+0·0009
(5)	0·0505	16	15	0·0506	+0·0001

Estimation of Vanadium and Chromium when present together.

For the estimation of both vanadium and chromium when present together, the following method was worked out: The solution containing the vanadium and chromium, both in the higher condition of oxidation, was divided into two portions. Into one portion of the solution, made slightly acid with hydrochloric acid, sulphur dioxide was passed until the reduction of the vanadium and the chromium was complete; the solution was then boiled in a current of carbon oxide until the last traces of sulphur dioxide were expelled. To the cooled solution a sufficient excess of potassium ferricyanide and potassium hydroxide were added in solution. By this process the chromium was oxidized from the condition of Cr_2O_3 to the condition of CrO_3 and the vanadium from the condition of V_2O_4 to the condition of V_2O_5. After allowing the solution to stand a few minutes, a solution of barium hydroxide was added to complete precipitation. The combined precipitates of barium chromate and barium vanadate were filtered off on asbestos and thoroughly washed; the filtrate was made acid with dilute hydrochloric acid and titrated with a known amount of permanganate in excess, and the excess titrated with $\frac{n}{20}$ potassium ferrocyanide, according to the method given above.

In the other portion of the solution the vanadium was determined as follows: The solution, about 100 cubic centimeters in volume, was made acid with from 10 to 15 cubic centimeters of glacial acetic acid, and hydrogen peroxide was added. The solution was then heated to boiling and boiled for a few minutes; by this process the perchromic acid and the pervanadic acid, which were first formed in the cold, were decomposed, the chromium being reduced to the condition of Cr_2O_3, while the vanadium remained in the condition of V_2O_5. The solution was diluted somewhat, and a solution of lead acetate was added to complete precipitation of the lead vanadate; the chromium, being in the condition of Cr_2O_3, was not precipitated. The solution was stirred vigorously to coagulate the precipitate, and was heated to boiling, which had the effect of making the precipitate more compact. The precipitate was filtered off on asbestos, washed thoroughly, and dissolved in potassium hydroxide. The solution was made strongly acid with sulphuric acid, whereby the lead was precipitated as the sulphate, while the vanadic acid remained in solution. A current of sulphur dioxide was then passed through the solution until the blue color indicated complete reduction of the vanadium to the tetroxide condition; and the sulphur dioxide was expelled by boiling in a current of carbon dioxide. The warm solution was then titrated with permanganate until the first permanent pink color appeared; and this could be easily recognized in the presence of the white precipitate of lead sulphate.

This titration gave a measure of the amount of vanadium present; and by subtracting the number of cubic centimeters of permanganate used in this titration from the number of cubic centimeters used in the preceding titration, the number of cubic centimeters corresponding to the oxidation of the chromium from Cr_2O_3 to CrO_3 was obtained.

The results of the determinations are given in Table IV.

TABLE IV.

	V_2O_5 taken grm.	CrO_3 taken grm.	V_2O_5 found grm.	Error grm.	CrO_3 found grm.	Error grm.
(1)	0·1139	0·1010	0·1134	—0·0005	0·1010	±0·0000
(2)	0·1139	0·1010	0·1139	±0·0000	0·1017	+0·0007
(3)	0·1139	0·1010	0·1134	—0·0000	0·1019	+0·0009
(4)	0·1139	0·1010	0·1142	+0·0003	0·1019	+0·0009
(5)	0·1139	0·1010	0·1131	—0·0008	0·1015	+0·0005
(6)	0·1139	0·1010	0·1134	—0·0005	0·1016	+0·0006
(7)	0·1139	0·0505	0·1139	±0·0000	0·0507	+0·0002
(8)	0·1139	0·0505	0·1134	—0·0005	0·0507	+0·0002
(9)	0·0569	0·0505	0·0565	—0·0004	0·0505	±0·0000
(10)	0·0569	0·0505	0·0563	—0·0006	0·0508	+0·0003

ART. XII.—*Ludwigite from Montana;* by WALDEMAR T. SCHALLER.

Occurrence and Association.

THE ludwigite here described was collected at Philipsburg, Montana, by Mr. Donald F. MacDonald and sent to the chemical laboratory of the Survey for determination by Mr. F. C. Calkins. It is stated to occur in metamorphosed limestone with large bodies of magnetite. An examination of a thin section showed that a member of the olivine group was sprinkled throughout the ludwigite and in addition a minute amount of a carbonate and a secondary fibrous mineral was present.

The ludwigite forms small spherulites composed of radiating fibers of a very dark green or nearly black color. In its physical properties it resembles the original ludwigite from Hungary. Under the microscope with high magnification the fibers extinguish parallel and show a strong pleochroism, parallel to the elongation a sea-green, normal thereto a chestnut-brown with stronger absorption in the brown than in the green. The refractive index is much higher than 1·67. The olivine mineral has a mean refractive index of about 1·66 and cleavage sections, parallel to *b* {010}, showing α and β have refractive indices lying between 1·65 and 1·66. The mineral must therefore be very low in ferrous iron and is referred to forsterite. As no calcium was noted in the analysis, the carbonate is either magnesite or siderite.

Analysis.

The sample free from magnetite but containing a small quantity of forsterite and minute amounts of the colorless fibrous mineral and the carbonate, gave on analysis the following results, the figures in the last column showing the values with the forsterite and carbonate deducted and the analysis recalculated to 100 per cent.

The ferrous iron was determined by a modification of Pratt's method,* using finely ground material. Some experiments conducted by Dr. Hillebrand on samples of this mineral showed that the oxidizing effect of grinding on the ferrous iron was slight. The first value for alumina (1·98 per cent) was obtained as the difference between the gravimetric determination of R_2O_3 and the subsequent volumetric titration

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* Hillebrand, W. F. The Analysis of Silicate and Carbonate Rocks, Bull. 305, U. S. Geol. Survey, 1907, p. 138.

Analysis of Ludwigite from Montana.

	Analysis of ludwigite mixed with forsterite and carbonate.				Analysis of ludwigite.
	1	2	3	Average	
FeO	6·12	5·53	5·74	5·79	7·27
MgO	39·09	38·60	39·42	39·04	33·78
Total iron	36·33	36·01	----	----	
Fe_2O_3	----	----	----	29·73	37·37
SiO_2	8·97	8·74	8·85	8·85	----
Al_2O_3	1·98	1·64	----	1·81	2·27
H_2O+	·97	----	----	·97	1·24
H_2O-	·91	·95	·85	·90	1·13
CO_2	·28	·43	----	·36	----
B_2O_3	13·48	----	----	13·48	16·94
				100·93	100·00

of the iron with permanganate solution. The iron and aluminum chloride solution was repeatedly evaporated with methyl alcohol to expel all the boric acid. The second value (1·64 per cent) was determined by precipitating the alumina by phenylhydrazine, as described by Allen.* As the two determinations agree fairly well, the presence of a small amount of alumina in the sample seems well confirmed. The higher result of the first case is probably due to the retention of a small amount of boric acid. Whether the alumina belongs to the ludwigite or to one of the accompanying minerals is difficult to decide, but it has here been included in the borate. The boric acid content has also been determined by Wherry and Chapin,† who give as the average of their results 12·82 per cent B_2O_3, a value slightly lower than the one here given.

The water content, though small, is still of sufficient importance to merit consideration. While no definite conclusion has been reached, it is believed that most, if not all, of the water is really unessential to the mineral. The determinations were made on the finely ground material and considerable water was thereby unquestionably taken up by the mineral.‡ As some water may also have been furnished by the secondary fibrous material, it therefore seems justifiable to conclude that a good part, if not all, of the water reported in the analysis is extraneous. It has been entirely omitted in the consideration of the ratios deduced from the analyses.

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* Journ. Amer. Chem. Soc., vol. xxv, p. 421, 1903. See also Bull. 305, U. S. Geol. Survey, p. 95.

† Determination of Boric Acid in Insoluble Silicates, E. T. Wherry and W. H. Chapin. Journ. Amer. Chem. Soc., vol. xxx, p. 1691, 1908.

‡ For data on this point, see this Journal, vol. xxv, p. 328, 1908.

Discussion of Formula.

From the figures of the average analysis, the ratios were calculated and found to be as follows:

Ratios of ludwigite analysis.

MgO	9760		7532	4·00	3·57 MgO
FeO	804				·43 FeO
Fe_2O_3	1858	[Less 1475 Mg_2SiO_4	2035	1·08	
Al_2O_3	177	and 82 $MgCO_3$]			
SiO_2	1475				
CO_2	82				
B_2O_3	1926		1926	1·02	

The ratios agree well with the formula generally given for ludwigite, $4RO.Fe_2O_3.B_2O_3$ The high water content obtained by Whitfield,* on the Hungarian material, namely 3·62 per cent, is substantiated neither by the analysis of the Montana mineral, as given above, nor by the analysis of the material from Hungary, as described beyond. Yet both samples yield about a per cent of water which is at present impossible to prove foreign to the mineral and may, in time, be shown to be an essential constituent thereof. If the water given off above 107° (H_2O+) be considered as essential to the mineral, a formula of about the proportions $RO : Fe_2O_3 : B_2O_3 : H_2O = 16 : 4 : 4 : 1$ would result.

While the ratios agree well with the general formula of ludwigite, the amount of ferrous iron is too small (even by referring all the ferrous iron in the analysis to ludwigite and none to either the forsterite or the carbonate) for the formula $FeO.Fe_2O_3.3MgO.B_2O_3$. From the data given above, the formula for the Montana ludwigite may be written $\cdot57MgO. \cdot43FeO. 3MgO. B_2O_3$, showing an isomorphous mixture of a *ferrous* ferric magnesian borate with a *magnesian* ferric magnesian borate, the latter being in excess.

As has been previously shown by the analyses of Ludwig and Sipöcz and of Whitfield and confirmed by the analysis given beyond, the Hungarian mineral approximates closely to the definite formula $FeO.Fe_2O_3.3MgO.B_2O_3$, though one analysis by Ludwig and Sipöcz shows a slight deficiency in the ferrous iron. The mineral from Montana, however, is very much lower in the ferrous iron and correspondingly higher in the magnesia, the ratios of $B_2O_3 : Fe_2O_3 : FeO + MgO$ remaining constant. There is here, then, sufficient evidence of the existence of magnesian ferric borate, $MgO.Fe_2O_3.3MgO.B_2O_3$, free from ferrous iron, not yet found in nature in the pure state but preponderant in the Montana ludwigite, being present in isomorphous mixture with the corresponding ferrous ferric magnesian borate, to the extent of 57 per cent or over half. If some of the ferrous iron present in the sample belongs to the forsterite or the carbonate, the percentage of the magnesian borate would be still greater.

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* Whitfield, this Journal, vol. xxxiv, p. 284, 1887.

Ludwigite from Hungary.

For comparison with the above, an analysis was also made of the ludwigite from Hungary. The quantitative analysis, made on the finely radiating black mineral, is as follows:

Analysis of ludwigite from Hungary.

	1	2	3	Average
FeO	15·84	15·68	15·80	15·84
MgO	28·86	28·88	....	28·88
Total iron as Fe_2O_3	53·35	52·74	53·72	....
Fe_2O_3	....	....	....	35·67
H_2O-	·50	·52	....	·51
H_2O+	·78	·86	....	·82
CO_2	·90	....	....	·90
Insol.	·32	·40	....	·36
B_2O_3	[17·02]	....	....	[17·02]
				100·00

The ratios from the average analysis give, after deducting sufficient MgO for the CO_2 to form magnesite, the formula $FeO.Fe_2O_3.3MgO.B_2O_3$, as shown below.

Ratios of ludwigite analysis.

FeO	·220	·99
MgO	·702	3·06
Fe_2O_3	·223	1·00
B_2O_3	·243	1·09
CO_2	·020	....

Summary.

The isomorphous relation of the FeO and MgO in ludwigite can be well shown by bringing together the available analyses, which also shows how closely the mineral from Hungary agrees with the calculated values for the pure ferrous-iron ferric magnesian borate. The first column gives the calculated values for $FeO.Fe_2O_3.3MgO.B_2O_3$, the second, third, fourth, and fifth the analyses of the Hungarian mineral and the sixth that of ludwigite from Montana.

Analyses of ludwigite.

	1	2	3	4	5	6
	$FeO.Fe_2O_3$ $3MgO.B_2O_3$	Ludwigite from Hungary analyzed by:				Ludwigite from Montana
		Ludwig & Sipöcz	Schaller	Whitfield	Ludwig & Sipöcz	
FeO ..	17·01	17·67	15·84	15·78	12·46	7·27
MgO ..	28·61	26·91	28·88	30·57	31·69	33·78
Fe_2O_3 ..	37·81	39·29	37·67	35·93	39·92	37·37
Al_2O_3 ..	....	....	....	....	....	2·27
B_2O_3 ..	16·57	15·06	[17·02]	12·04	16·09	16·94
MnO ..	....	tr.	....	0·16	tr.	....
H_2O- ..	....	....	0·51	3·62	....	1·13
H_2O+ ..	....	....	0·82		....	1·24
SiO_2 ...	....	....	0·36	....	....	....
CO_2 ...	....	....	0·90	....	....	....
	100·00	98·93	100·00	100·10	100·16	100·00

The second analysis (column 5) by Ludwig and Sipöcz shows a slight replacement of the ferrous iron by magnesia, carried out to a much larger extent in the mineral from Montana. All new occurrences of ludwigite should be carefully examined chemically, as the possibility of the existence of the ferrous-iron free magnesian borate is strongly indicated by the above analyses.

Chemical Laboratory, U. S. Geological Survey.

ART. XIII.—*Chemical and Optical Study of a Labradorite;*
by W. E. FORD and W. M. BRADLEY.

THROUGH the courtesy of Dr. George F. Kunz the Brush Mineral Collection received some time ago a suite of water-worn pebbles of a perfectly clear and almost colorless mineral which on investigation proved to be a labradorite. The locality from which the specimen came is given by a correspondent of Dr. Kunz as the Altai Mountains, in Mexico, just across the international boundary from New Mexico. The specimens offered ideal material for chemical and optical study, and as plagioclase feldspars of this composition are not very frequent in occurrence, it was thought that a brief description of the mineral would be of interest.

The analysis by Bradley gave the following results:

	I	II	Average	Molecular Ratios	
SiO_2	51·27	51·21	51·24	·8483	
Al_2O_3	30·89	30·79	30·84	·3017	
CaO	13·52	13·65	13·59	·2422	
Na_2O	3·74	3·78	3·76	·0605	·0623
K_2O	0·18	0·16	0·17	·0018	
Fe_2O_3	0·71	0·75	0·73	....	
Ign	0·24	0·15	0·24	....	
	100·55	100·59	100·57		

	Molecular Ratios	Albite Molecule	Anorthite Molecule
SiO_2	·8483	·3738 (or 6·00)	·4745 (or 2·00)
Al_2O_3	·3017	·0623 (or 1·00)	·2348 (or 1·009)
$Na_2O + K_2O$	·0623	·0623 (or 1·00)	
CaO	·2422		·2422 (or 1·021)

Ratio of albite molecule to anorthite molecule, 1: 1·918.

The small amount of water is considered to be hydroscopic and the 0·7 per cent of ferric oxide is assumed to be due to small inclusions of hematite as explained in a later paragraph. On calculation the analysis gives, as is shown above, the ratio of the albite molecule to that of anorthite as 1 : 1·918. This places the mineral in about the middle of the labradorite series.

The specific gravity of the material analyzed was found to be 2·718. The theoretical value for the specific gravity of a mixture corresponding to $Ab_1An_{1.918}$ obtained by using the values of the specific gravities for the end members of the series as given by Day and Allen,* (Albite = 2·605; Anorthite = 2·765) was found to be 2·710.

The mineral was water-clear and almost colorless, showing only in the larger pieces a faint tinge of yellow. In some cleavage fragments, when viewed perpendicular to the poorer cleavage face *b* (010), a copper-like reflection was seen, similar to that in the sun-stone from Tvedestrand, Norway. It was evidently due to minute tabular inclusions of some iron oxide, probable hematite, which lay in planes parallel to *b* (010). On examination under the microscope with a high-power lens these inclusions were seen to be very minute and without crystal outline, many of them possessing a curved shape similar to that of a comma. One fragment showed larger inclusions which in this case were arranged parallel to both cleavage directions. These larger inclusions were more regular in shape, being in general like very thin wafers with a circular or slightly elliptical outline and having a lens-shaped cross-section. A thin section of this specimen ground parallel to one of its cleavage surfaces showed under the microscope, first a series of nearly circular inclusions of a copper color scattered irregularly over the field and which were lying parallel to the plane of the section, and second, a series of thin, lens-shaped inclusions arranged in parallel lines, these latter being the cross sections of the inclusions lying in the cleavage plane perpendicular to the section.

Of the two cleavages, the one parallel to the base, *c* (001), was excellent, while, as is usually the case with the feldspars near the anorthite end of the plagioclase series, the cleavage parallel to *b* (010) was imperfect and difficult to obtain. Several measurements of the cleavage angle were made on different fragments, the two best giving the following closely agreeing angles, 85° 49′ and 85° 50′.

Sections were ground parallel to each cleavage face and the angles of extinction were measured in sodium light with the trace of the cleavage of the other face. On account of the imperfect cleavage parallel to *b* (010), the two sections that were made parallel to this face were carefully adjusted so that in each case they made with the basal cleavage an angle having a value within a few minutes of theory. Sections parallel to *c* (001) were easily made, but because of the imperfect nature of the cleavage parallel to *b* (010) it was not always possible to be certain of this direction in the section. The method adopted was to find a cleavage fragment that showed both cleavages present, as proven by the measured angle between them, and then to grind the section parallel to

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*The Isomorphism and Thermal Properties of the Feldspars; Carnegie Institution Publication, No. 31, p. 74, 1905.

c (001), making note of the direction of the line of cleavage of *b* (010).

The average values of a series of readings of the extinction angles of the two sections made in each case with the direction of cleavage of the other face were as follows:

		Measured	Calculated
on *b* (010)	=	−24° 37	−25° 33
on *c* (001)	=	−12° 13	−11° 58

In the second column are given the theoretical values of the extinction angles of the respective sections, calculated by Mallard's formula, as given by Schuster.* The agreement of the measured and calculated values is fairly satisfactory. Both sections when viewed in convergent polarized light show the emergence of an optic axis just beyond the field of the microscope.

Laboratory of Mineralogy,
Sheffield Scientific School, Yale University,
New Haven, June, 1910.

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* Min. Petr. Mitth., v, 192, 1882.

ART. XIV.—*Halley's Comet;* by GEORGE F. CHAMBERS, F.R.A.S.*

THIS brochure, extracted almost verbatim from the author's extended work, The Story of the Comets, published last year, is intended to meet the large demand occasioned by the return of Halley's comet for knowledge with regard to this comet and such facts regarding comets in general as are necessary to make the account of an individual comet intelligible in itself.

It contains all that needs to be known by the general reader of the past history of this comet and also of its present appearance up to the time of its perihelion passage, shortly after which this pamphlet was published.

The purpose of the present article is to present for reference in a form accessible to readers of this Journal a summary of this pamphlet, supplemented by reports of the later period of the comet's visibility sufficient to give a comprehensive view of the knowledge acquired from the latest apparition of what is generally considered to be, historically at least, the most interesting of all comets.

In anticipation of the return of the comet elaborate preparations were made by mathematical astronomers for its early discovery. The labor of preparation was much increased by the large perturbation by Jupiter soon after the perihelion of 1835. Nevertheless as early as 1864 Pontécoulant assigned a date for the next perihelion which proved to be a close approximation, and the final predictions of Cowell and Crommelin published in January 1909 were but three days in error, the actual date of perihelion being April 19. This result was considerably closer than any obtained for the return in 1835.

The competition for the earliest discovery of the comet by photography was very keen and aroused much interest the world over. The first announcement of its appearance was made by Wolf from a plate taken September 11, 1909, at Heidelberg. Soon after it was found to have been fixed on a plate taken at Greenwich, Sept. 13, and some months later it was identified on a plate taken by Keeling at Helwân in Egypt late in August. Search had begun at Greenwich and Heidelberg as far back as the early part of 1908, while an unsuccessful search by Dr. O. J. Lee at the Yerkes Observatory in December, 1908, led him to conclude that it was not then as bright as the 17th magnitude.

The first visual observation of the comet was made at the Lick Observatory with the 36-inch reflector on October 16.

During November and December observations were numerous at various observatories, but on the whole they were neither very satisfactory in themselves nor consistent with one another. It seems altogether probable that the brightness of the comet fluctuated irregularly in a manner not dependent on its distance from the earth and sun, and this appears to the present writer to be the one fact of any special scientific interest noted concerning the comet during its entire period of visibility.

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* Oxford, Clarendon Press. New York, Henry Froude, pp. 48.

Rev. E. T. R. Phillips, at Ashstead in Surrey, observed it on ten nights between November 22 and December 29 and reported as follows:

"It has never regained the brightness of November 22, when it was quite unexpectedly about magnitude 10, but it exhibited some fluctuations in light. After being very faint at the end of November (nearly as low as magnitude 12) it revived somewhat in the early part of December, but on December 6, under excellent observing conditions, it was again as faint as magnitude 11·5 or 12. On December 8 it could just be glimpsed occasionally with 3½ inches eccentric stop and its magnitude was probably about 11. It was not seen again owing to bad weather till 18th, when it was surprisingly faint considering its greater proximity, probably below magnitude 12, and on 20th it was probably below magnitude 12·5. On 25th the moon was nearly full, and the comet invisible, but it was again observed on 28th. On that occasion it appeared about as difficult as when it was first seen at Ashstead on November 16. The estimated magnitude was 13."

During January, February and March the comet approached superior conjunction, and observations were for this reason limited and unimportant, though during January it became visible to the naked eye under favorable conditions, but not in the United States on account of its south declination.

Shortly before its perihelion passage, April 19, the comet passed behind the sun and appeared to the west of it in the early morning, rising at the earliest about 3 A. M.

Observations were now again limited by the brief period of visibility before strong twilight, the prevalence of cloudy weather and the light of the moon, which was full on April 24. During the first part of May, while it had not yet much receded from the sun and was still approaching the earth, the tail attained its greatest brightness but in length was very considerably foreshortened. For a short time near perihelion it was traced in the morning sky to a length of 140°. After passing between the earth and sun on May 19, when it was very nearly in true conjunction, the tail was displayed at a large angle to the line of sight in the evening sky, and after the full moon of May 22 at a good distance above the horizon, but by reason of its increased distance from the sun it was much diminished in brightness.

By the great majority of non-professional observers, who had been long waiting for a view, it will be remembered as it appeared around May 24 between 9 and 10 P. M., some 10° below Regulus and about of the 2d magnitude, with a tail faint but well defined, straight and easily discernible to the naked eye for a length of 25°, pointing almost directly toward the planet Jupiter, which was some 40° from the nucleus.

The curvature of the tail was considerable but was not conspicuous either before or after its perigee because the plane of the curvature was but little inclined to the line of sight. It was sufficient so that the tail was seen in the morning sky on the 20th of April, the day after the comet passed between the earth and the sun, the nucleus at the same time being in the evening sky.

It is not unlikely that this phenomenon was due to the formation of two separate tails of Bredechins types, extending on opposite sides of the earth at the same time.

In comparison with former appearances there is considerable evidence that the tail was somewhat less brilliant than heretofore, though the difference was not very remarkable nor more than was to be expected.

Considerable interest was felt in the passage of the earth through the tail, which on account of the curvature probably occurred on the 20th of April instead of the day of conjunction. Indeed, on account of the uncertainty as to the distribution of the cometic matter and the amount of curvature, it is not possible to assert positively that the earth actually passed through any portion of the tail.

No evidence of the occurrence was obtained in the form of afterglow or shooting-stars, nor was any special effort to this end made by astronomers. A suggestion of analyzing great volumes of air for several days after the 20th to detect unusual chemical constituents was not considered worth the trouble, if indeed it were practicable.

The occurrence of this phenomenon took a strong hold on the popular imagination, and in spite of all that was published as to the impossibility of any harm from it or the possibility of even detecting it, ignorant people were genuinely alarmed and great numbers kept watch in the streets of the cities during the night of the 19th, though in fact, as before explained, the earth did not actually pass through the tail until the 20th, if at all.

At the time of the publication of this article no detailed reports of spectroscopic observations have appeared.

WILLIAM BEEBE.

SCIENTIFIC INTELLIGENCE.

I. Geology.

1. *The Cement Resources of Virginia west of the Blue Ridge;* by Ray S. Bassler. Bull. No. II–A, Virginia Geological Survey 1909 [1910], pp. x and 309, and 30 plates.—The author has here brought together a great deal of information relating to the limestones and shale formations of the state west of the Blue Ridge. This information has been gleaned from all sources and especially from the extensive travels of the author throughout the state in tracing the various boundaries of the Ordovician formations. Many chemical analyses of the limestones are given. Stratigraphers will find here much new and detailed information regarding the Ordovician, Silurian, and Lower Devonian formations. The guide fossils to the more important cement-bearing formations are illustrated in plates and these will be of great service to the field worker in his age determination of the various deposits. The printing and illustrations are good and the book is above the average of state geological reports. C. S.

2. *Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma;* by Chas. N. Gould, D. W. Ohern and L. L. Hutchison. The State University of Oklahoma Research Bulletin, No. 3. Pp. 15 and 1 map. Norman, 1910.—The Pennsylvanian sediments of Oklahoma have a thickness of from 10,000 to 12,000 feet, of which at least three-fourths is shale. At definite intervals in these deposits occur limestones known as the Claremore (Fort Scott), Lenapah, Pawhuska and Wreford. On the basis of the position of these limestones the Pennsylvanian is divided into the Muskogee (9550 feet thick and coal-bearing), Tulsa (about 1200 feet thick), Sapula (about 1000), and the Ralston (about 800) groups. C. S.

3. *Yorkshire Type Ammonites;* edited by S. S. Buckman. London, 1910 (Wesley & Son).—The Jurassic (Lias and Oolite) ammonites of Yorkshire, inadequately described in the early days of geology by Young and Bird, John Phillips and Martin Simpson, are to be illustrated in this work by excellent photographs made mainly by J. W. Tutcher. Each species appears on independent sheets, as in the *Palaeontologia Universalis*, and reproduces the original description and new photographs of the type specimens where these are extant. The editor supplements this information by additional matter that he has gathered during a lifetime, modernizing each species. There are to be about 200 plates.

The work is to appear in about 16 parts of about 12 to 16 plates each and the edition is to be limited to 250 copies. Each part, post free, costs 3 shillings 6 pence. Two parts have now appeared having 24 plates, heliotype and half-tone, and 22 species descriptions. The work is necessary to all students of ammonites. C. S.

II. Miscellaneous Scientific Intelligence.

1. *Physical and Commercial Geography: A study of Certain Controlling Conditions of Commerce;* by Herbert Ernest Gregory, Albert Galloway Keller, and Avard Longley Bishop. Pp. vi, 469, with 3 plates. Boston, 1910 (Ginn & Co.).—The foregoing work contains the substance of courses given at Yale. In form and style it is a companion volume to Keller's Colonization, and is issued under Professor Keller's editorial supervision. Like that work, its purpose is to interpret rather than to enumerate or describe, and to deal with types rather than with details.

The subject matter is three-fold and the work is divided into three corresponding parts. Part I (Gregory) discusses the physical environment, giving attention chiefly to those features which clearly affect the life of man, including, however, a brief account of the struggle for existence among plants and animals. Part II (Keller) is entitled "Relation of Man to Natural Conditions," but actually covers both natural and human controls of commerce, closing with a brief consideration of commercial policies. Part III (Bishop), on "The Geography of Trade," is devoted to the United States and its possessions, the British Empire, and the German Empire. Within each country, however, the material is assembled by industries rather than by sections: for example, there are separate chapters on the vegetable, animal, mineral, manufacturing, transportation, and merchandizing industries of the United States. At the end there is also a chapter on miscellaneous products not produced chiefly in the countries already treated.

In point of method the book is consequently of the fusion type represented by Adams, dealing both with regions and with world industries. It is liberally supplied with cross references and has a good statistical appendix. It is, further, assumed that the student will have access to some text on physical geography and to an atlas of physical, historical and political geography.

The work unquestionably marks a distinct advance in the treatment of economic geography. It is intended primarily for college classes and it will assuredly be welcomed by all who believe that economic geography is (or should be) something more than a compend of isolated and unrelated statistics. The book also contains much of interest to the general reader, provided he be capable of consecutive thought.

EDWARD VAN DYKE ROBINSON.

University of Minnesota.

2. *Soil Fertility and Permanent Agriculture;* by Cyril G. Hopkins. Pp. xxiii, 653. Boston (Ginn & Company).—This work is "dedicated to the Association of American Agricultural Colleges and Experiment Stations, the rightful guardians of

American Soils." The author states that his object is "to teach the science of soil fertility and permanent agriculture" by giving facts rather than theories.

The work is divided into four parts and an appendix. Part I (pp. 1–158) embraces a discussion of molecules, valence, certain fundamental chemical laws, the more common chemical elements, radicals, acids, bases, salts, and certain principles of chemical nomenclature. It treats of the chemistry of plant nutrition and synthesis ; minerals of agricultural importance ; and soil formation, classification, and description, as conducted by the Bureau of Soils of the United States Department of Agriculture. It also contains a brief reference to crop requirements, and to sources of plant food. This part, though possibly capable of being read with profit by the farmer, is too technical in character for those not studiously inclined ; it will, however, be found useful to those students of agriculture who have not already laid a broad chemical foundation, and who wish in a brief way to secure at least an elementary idea of the relation of chemistry to soils and to plant production.

Part II (pp. 159–342) is devoted to ground limestone and its use, to the phosphorus compounds more commonly used for agricultural purposes; to organic matter in its relation to soil improvement; and to the fixation of nitrogen by direct bacterial agencies, as well as through the medium of symbiosis. Following a brief chapter on systems of rotations for grain farming, is an extended chapter on farm manures, bone meal, basic slag phosphate, and phosphate rock. The special emphasis on the latter is doubtless due to the efforts of the author to promote its use as a fertilizer on certain of the soils of Illinois.

Part II closes with a lengthy chapter on theories of soil fertility, beginning with those of van Helmont, advanced about three hundred years ago, and extending to certain recent and much disputed theories advanced and supported chiefly or wholly by the Bureau of Soils of the United States Department of Agriculture. The author points out that a recent investigator of the question in Kentucky finds that these views are not generally accepted and taught in the agricultural colleges of the United States, as had been claimed by the Bureau of Soils at a previous congressional hearing. He also takes occasion to express his opinion concerning these views with characteristic energy and vigor.

Part III is devoted to soil investigations by culture experiments. In this connection extended reference is made to the long continued field experiments at Rothamsted, England. Special attention is also given to the field experiments at the Pennsylvania State College, at Wooster, Ohio, in the South, in Canada, and in the author's own state of Illinois. The closing chapter deals with pot-culture and water-culture experiments in comparison with field results. In this connection the author calls attention to certain shortcomings of the paraffined wire-basket method of the Bureau of Soils, as a means of determining actual soil deficiencies.

Part IV treats of prepared commercial fertilizers, and briefly of indirect manures, of agencies protective against plant diseases and insect pests, of critical periods in plant life, losses of plant food from plants and soils ; also of factors of importance in crop production, and of those involving success in farming.

The Appendix contains more or less miscellaneous matter, and tables of agricultural interest.

The work is original in its composition, but is perhaps too controversial to meet accepted ideas, if intended as a text-book. It lays unusual emphasis on certain matters like limestone and phosphate rock, but contains a vast amount of matter which will cause it to be welcomed as a valuable addition to our agricultural literature.

H. J. WHEELER.

3. *Publications of the Smithsonian Institution.*—Bureau of American Ethnology, Bulletin 48. The Choctaw of Bayou Lacomb, St. Tammany Parish, Louisiana; by DAVID I. BUSHNELL, Jr. Pp. viii, 37, with 22 plates and 1 figure. Washington, 1909.

The following volumes in the series of Smithsonian Miscellaneous Collections have also appeared: Vol. 51, No. 4. Hodgkins Fund (Publication 1869). The Mechanics of the Earth's Atmosphere: A Collection of Translations; by CLEVELAND ABBE. Third Collection. Pp. iv, 617.

Vol. 54, No. 3. The Constants of Nature. Part V. A Recalculation of the Atomic Weights. Third edition, revised and enlarged; by FRANK WIGGLESWORTH CLARKE. (Publication 1923.) Pp. iv, 548. Noticed on p. 80 of this volume.

Volume 55. (Publication 1920.) Bibliography of Aeronautics; by PAUL BROCKETT. Pp. xiv, 940.

Vol. 56, No. 1. The Scales of the African Characinid Fishes; by T. D. A. COCKERELL. Pp. 10, with 2 plates. (Publication 1929.) No. 3. The Scales of the Mormyrid Fishes with Remarks on Albula and Elops; by T. D. A. COCKERELL. (Publication 1931.) Pp. 4, with 3 figures. Washington, 1910.

OBITUARY.

JOHANN GOTTFRIED GALLE, the German astronomer and the first observer of the planet Neptune, died at Potsdam on July 10, at the age of ninety-eight years.

Dr. CHARLES ABIATHAR WHITE, the geologist, died at his home in Washington on June 29, at the age of eighty-four years. He was professor of Natural History in the University of Iowa from 1867–73, and in Bowdoin College from 1873–75. He was also State Geologist of Iowa from 1866–70, and was connected as geologist and paleontologist with the U. S. Government Surveys from 1874–92 ; he was also actively associated with the Smithsonian Institution and the U. S. National Museum. His original contributions to geology and paleontology were numerous and important.

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'rof. W. G. Farlow.

VOL. XXX. SEPTEMBER, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
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VOL. XXX—[WHOLE NUMBER, CLXXX.]

NO. 177—SEPTEMBER, 1910.

NEW HAVEN, CONNECTICUT.

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As mentioned in my previous adv., I have still left a few of the fine Malachite and Rhodonite gem boxes, also several cups and trays. In addition to the above, I have received a large consignment of cut gems, as follows: emeralds from 1–13 carats; aquamarines; rubellites; olivines; amethysts; green garnets; topaz, (blue and white,) all sizes. In addition to these, I also secured some very fine ornamental wooden boxes made by the peasants from a rare wood which comes from northern Siberia; the wood is splendidly grained, very light and of excellent workmanship; they consist of the following: glove boxes, jewel boxes, stationery boxes, card, cigarette, cigar boxes, watch cases, etc.

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[FOURTH SERIES.]

ART. XV.—*The Use of the Grating in Interferometry;*[*] by C. BARUS.

1. *Introductory.* It was pointed out elsewhere[†] that on replacing the symmetrically oblique transparent mirror in Michelson's adjustment by a glass grating,[‡] *gg*, fig. 1 (for instance), it is possible, with ordinary plate glass and a non-silvered grating, to produce interferences between pairs of diffracted spectra, *D'D''*, if returned by nearly equidistant mirrors *M* and *N* to a telescope in the line *D*. Both of these spectra are very brilliant and not very unequally so, and the coincidence of spectrum lines, both horizontally and vertically, brings out the phenomenon. This is of the ring type and not of the line type heretofore (l. c.) discussed; but it occupies the whole field of the spectrum from red to violet. One obtains brilliant large confocal ellipses with horizontal and vertical symmetry, and the spectrum lines, simultaneously in focus, may serve either as major or minor axes. Their interferometer motion is twofold in character, consisting of radial motion combined with a drift of the figure as a whole in a horizontal direction. Naturally a fine slit is of advantage, but the experiment succeeds with a wide slit, especially in the red, even after spectrum lines vanish.

Such ellipses (as I shall call them, though they are probably ovals) as have their centers in the field are clearly due to reflection from the same surface as shown in figure 1; curved lines or ellipses with remote centers are due to simultaneous reflections of the component rays from the opposite faces of the grating, so that the angle of the wedge of glass cannot be excluded. All owe their vertical and horizontal symmetry to the vertical slit and horizontal spectrum. The ellipses are identically present in the successive orders of spectra at once.

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[*] Abridged from a Report to the Carnegie Institution of Washington.

[†] Science, xxxii, p. 92, 1910; cf. Phil. Mag., July, 1910.

[‡] My thanks are due to Prof. J. S. Ames, who was good enough to lend me this grating.

These elliptical fringes thus embody with the preceding (l. c.) the common property of being duplex in character ; only here the motion of dark rings to or from the centers of the ellipse, as a fine adjustment, is associated with a displacement of the fringes bodily through the spectrum (coarse adjustment).

This displacement may be from red to violet or from violet to red as the virtual air-space increases in thickness, depending upon the adjustment, as will presently appear. In other words, for a given small interferometer motion of mirror, there is in general less displacement of fringes bodily than radial motion of fringes to or from the center. Slight deflection of the mirror is chiefly accompanied by radial motion of the fringes.* The effect thus produced is to give sharpness to the interference pattern, which soon vanishes for approximate adjustments of spectra.

Similarly the micrometer screw produces a rapid passage of the pattern through its maximum size, a play of the screw of $\cdot 1^{cm}$ being sufficient to pass from fringes of one extreme of small size, through the maximum size to the final extreme. On the other hand, there are many regions of interference ; in fact, different groups of interferences may sometimes be in the field at once, or more usually corresponding to slightly different angles between the mirrors and grating.

All admissible angles, provided that symmetry is maintained (the virtual plane of the grating bisecting the angle of the mirrors), bring out the phenomenon. This points to the fact that the earlier phenomenon referred to (l. c.) in which the center or normal ray was virtually at an infinite distance, is now produced near an accessible center, even if this is not actually in the field. However, in the earlier case when the angle of incidence is zero, curved lines may also be obtainable.

Experiments with a silvered grating showed no advantage, whether the transparent film covered the grating or the plane face of the glass. In fact in case of good adjustment the phenomenon is so strong as to need no accessory treatment. This is, in fact, one of its advantages. A great difficulty in adjustment is the occurrence of stationary fringes due to the rear face of the grating. These may even wipe out the spectrum lines; but usually they lie at a finite focus and are not seen with a sharp spectrum. Fortunately many positions are available for obtaining the ellipses, so that a satisfactory one is easily found. Unless all overlapping spectra show sharp lines the adjustment is very tedious. The amount of grating space is less than 1 sq. cm., though, of course, a larger size is convenient for experiment.

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* This changes the effective thickness of the grating.

2. *Special properties.*—The motion of the ellipses bodily across the spectrum, corresponding to the increased or decreased virtual air space (micrometer screw), shows that whereas the vertical dimension or axes (direction of fixed color) do not appreciably change,* the horizontal axes grow rapidly smaller; i. e., the ellipse is more eccentric from red to violet. With the grating used, however (about 2800 lines per cm.), the major axis remained vertical, i. e. the circular form was not reached throughout the first order even in extreme red.

It follows from this that in the second order the major axis of the ellipses will probably be horizontal, and this was found to be strikingly true. The figure, moreover, is necessarily coarser and the lights and shadows in greater contrast. In the third order the ellipses are drawn out horizontally to a correspondingly greater degree. Thus it is clear that with a more dispersive grating, the circular or even the horizontally elongated form must occur in the first order. Spectrum lines are very distinct, particularly in the second order. In all orders of spectra the centers of the ellipses are simultaneously on the same spectrum line and their vertical dimensions are about the same. Hence the spectrum lines may be used instead of cross hairs as they are fixed landmarks among the moving ellipses.

With replica gratings the center of the ellipses is usually remote; i. e., reflection does not easily take place at the grating surface. Apart from this the curved lines are good and strong. Samples must be tried out, in which the lines are as clear as possible in all the overlapping spectra. Six gratings of this kind were examined with about the same results. The centers of the ellipses could only rarely be brought into the field.

It has been stated that considerable width of slit is admissible. Moreover the focal plane of the collimator (convergent or divergent) light or the focus of the telescope makes little difference, though the condition of parallel rays is naturally preferable. An eye focused for infinity sees the fringes very well without the telescope and they may be also caught on a screen; but coming through a slit they are liable to be dark and the advantage of the telescope is obvious. The second order is particularly accessible for naked-eye observation, and the light and black appearance is accentuated, but they are liable to be irregular. Inclining the collimator moves the spectrum across the fringes vertically, while inclination of the telescope moves both equally. In this way the centers may often be found. With strong tipping, however, the figure becomes distorted or open above and below, as would be expected. If the light is intensified for projection or naked-eye work, there is also distortion.

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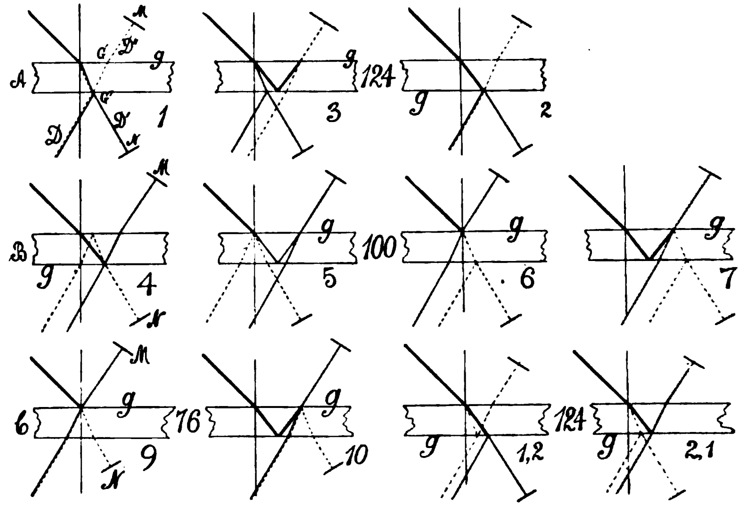
* Probably referable to increased refraction and decreased diffraction from red to violet.

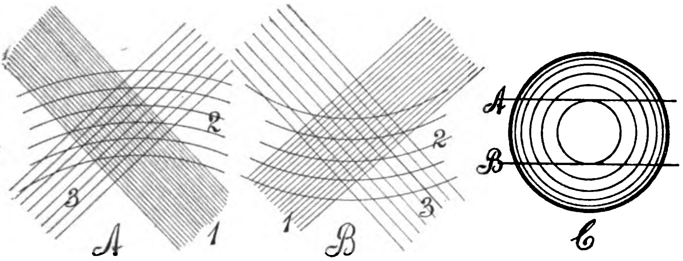
It is not necessary and apparently of little advantage to have the reflections from the mirrors *M* and *N* occur at normal incidence. In fact the patch of white light on the grating surface and the return patch of spectrum may be over an inch apart. Inasmuch as the spectra are rigorously coincident, it follows that (apart from the refraction of the thick plate glass) the grating must be symmetrical with respect to the mirrors; i. e., intersect the angle between them. Very little difference of size or shape is observable between extremes of such adjustment. Thus I rotated the grating about 10° (larger angles being unavailable), without appreciable effect, after one of the mirrors had been correspondingly adjusted.

FIG. 1.



On examination of the effective air distances of the mirrors *M* and *N* from the grating, it is found that three positions are favorable to interference; in the first case (case A), *M* is farther away than *N* from the corresponding faces of the glass plate; in the second (case B), they are about equidistant; finally in the third (case C), *N* is farther away, symmetrically with the first adjustment. For each case the admissible play of mirror (micrometer screw) does not much exceed 1^{mm} for ordinary magnification. The second equidistant adjustment brings out the lines or ellipses with distant centers, and there are usually three types easily found (after one has appeared), by slightly inclining either mirror around a horizontal axis by a tangent screw. Thus as seen in fig. 2, fine lines, say 135° to the horizontal, coarse, nearly circular lines, concave downward or upward as the case may be, and finally broad lines, say 45° to the axis, may appear in succession. If the grating is rotated 180° around its normal, convexity upward changes to concavity upward, showing the wedge angle of the glass plate to be effective. The micrometer screw will pass any of these forms through a succession of inclinations corresponding to the eccentric intersection of a group of concentric circles by a straight line. This is also shown in fig. 2; at *A* and *B* as observed for a fixed air space and at *C* on moving the micrometer in the *A* and *B* cases. These figures cover the coincident spectrum fields only. A solitary part of the field shows no interferences. For adjustment it is, therefore, necessary to cut off the spectra sharply above and below by limiting the length of slit. Of the three or four spectra present the coincidence may then be secured with least difficulty. With each such coincidence there goes a definite position of the micrometer screw (interferometer), and this is the initial difficulty of adjustment; i. e., to coördinate the various spectrum coincidences with the three screw readings.

Fig. 2.



The non-equidistant case of mirrors and grating corresponds to the ring types with the centers in the field. Hence both reflections take place from the same face of the grating. When the distance *GM* is shorter, *G'N* longer, I have noticed two or even three ellipses successively in the field, obtained by slowly inclining the mirror *N* about the vertical (tangent screw), with their centers in turn in the yellow-green, the blue and the green of the spectrum. They do not occur together. On turning the micrometer screw clockwise, they move from red to violet and vice versa.

When the distance *GM* is longer and *G'N* shorter, rings also occur; but only a single set was found. The spectrum lines not being clear, finding them was a matter of discrimination. When the micrometer screw is turned clockwise, however, they marched from violet to red, i. e., in *opposite* direction to the preceding. Thus the virtual air space *M-N*, which was increased in the preceding case, is here being decreased. This space is not generally zero. Moreover, violet travels radially more rapidly than red, for the same micrometer displacement. Hence the drift of ellipses agrees with the horizontal radial motion of the violet.

It is an astonishing result that when the grating is reversed (front face put rearward, but leaving the air space unchanged) the ring type is left in the field; though the solitary ring type may change to the multiple type. This is true for case *A* or case *C*. It is also true for the eccentric type case *B*, where line types single or multiple reappear at slightly different mirror angles. Briefly, rotation has no effect on the march of ellipses through the spectrum; but in case *B* it changes convex lines downward to concave lines, and vice versa. Nor has reversal of grating any effect on the march. The position of the grating with respect to the mirrors (three places being available) alone determines this result, certainly in the opposed cases *A* and *C*, and probably in case *B*.

The use of a compensator in either of the component rays is always accompanied by the two effects in question; i. e., there is both relatively large radial motion of the fringes and relatively small displacement. Within the field of the telescope one may therefore be evaluated in terms of the other, the two having the stated relation of coarse and fine adjustments. In case *B* the fringes will rotate, expand, or contract.

3. *Elementary theory.*—The endeavor must now be made to explain these results more in detail. For this purpose the diagrams of fig. 1 may be consulted.

In the grating used at an incidence of about 45°, the angle of diffraction in the first order was about 32° 39′ for the D_2 sodium line, there being about 2,847 lines to the cm., corresponding to a grating space of $D = {\cdot}0003512^{\text{cm}}$. Thus $\lambda/D = {\cdot}1677$. The index of refraction was assumed to be 1·53 for the same line.

The diagrams are drawn for an angle of incidence of 45° and for normal reflection from the mirrors *M* and *N*. In case of the grating given, the three positions of the grating at which interferences occur were about $\cdot 6^{\text{cm}}$ apart and are marked 124, 100, and 76 scale parts, on the micrometer screw normal to the grating. In other words, it was convenient to move the grating at the center of the spectrometer, rather than the mirrors M and N adjustably attached near the edge of the plate graduated in degrees.

In group A at 124, the short air path is to M, the long path to N; in group C at 76, the reverse is true. In group B at 100, the system is self-compensating and the air paths about equal.

In all cases the angle of diffraction, θ, is less than the angle of incidence, i. There are, of course, corresponding cases, $\theta > i$, which have not been drawn, because they merely duplicate the cases given, at a different angle. It is assumed that after more than one direct reflection or one diffraction, the interferences are no longer observable.

The diagrams 124 and 76 show that the two reflections of the component rays at the grating take place at the same surface. Hence the occurrence of centered figures or rings. On the contrary, the reflections in diagram 100 take place at the two different faces of the grating, respectively. Hence the angle of the grating is included and liable to produce eccentric ring systems. The center may be so far off that the dark lines are nearly straight, but they change their inclination as the vertical projection of the center moves horizontally through the field.

Some of these cases may coalesce in practice or they may destroy each other, more or less. I have taken a single incident ray from which may come two parallel emergent rays, which are brought to interfere by the telescope. It would have been just as convenient to have taken the two corresponding incident rays which interfere in a single emergent ray. From the position of the mirrors it is clear that the regularly refracted rays are not returned. Only rays *first diffracted* at the grating (where they may also be reflected) are returned by the mirrors.

As a whole we may distinguish two typical cases,—those in which both component rays are diffracted as in number 1 or refracted as in number 2, and those in which one component ray is refracted and the other diffracted. If i and θ' are the angles of incidence and diffraction in air, and r and θ the corresponding angles of refraction and diffraction in glass, the path differences $\triangle x$ are as follows:

No. 1. $\triangle x = 2\mu e/\cos\theta = 2{\cdot}2^{\text{cm}}$.
" 2. $= 2\mu e/\cos r + 2e\sin\theta'(\tan r - \tan\theta) = 2{\cdot}5^{\text{cm}}$.
" 3. $= 2\mu e/\cos\theta = 2{\cdot}2^{\text{cm}}$.
" 4. $=$ Zero.
" 5. $= -2\mu e/\cos\theta + 2\mu e/\cos r + 2e\tan r\sin\theta'$.

No. 6. Zero.
" 7. "
" 8. "
" 9. $\triangle x = -2\mu e/\cos\theta = 2{\cdot}2^{\text{cm}}$.
" 10. $= -2\mu e/\cos\theta = 2{\cdot}2^{\text{cm}}$.

Here μ is the index of refraction and e the thickness of the glass plate of the grating, and excess of path for the M ray is reckoned positive. These paths must be compensated by corresponding decrements and increments respectively of the air paths GM and GN. Ordinarily, these path differences in glass being fixed for the given angles θ, would fall away; but they vary essentially with color, and hence the degree of compensation is never the same for all colors.

Furthermore, although the wave fronts of the two rays are the same on emergence, this does not imply coincidence of phase even in such cases as numbers 1 and 2, for instance: the absolute lengths of paths in glass are quite different, although their differences are the same. Consequently the cases 1 and 2 would again interfere if superimposed, one case being first diffracted and the other first refracted.* The path differences are respectively,

$$\text{No. 1, 2:}\quad \triangle x = e\left(\frac{3\mu}{\cos\theta} - \frac{\mu}{\cos r} - (\tan r - \tan\theta)\sin\theta'\right) = 2{\cdot}1^{\text{cm}}$$

$$\text{No. 2, 1:}\quad = e\left(\frac{\mu}{\cos r} + \frac{\mu}{\cos\theta} + (\tan r - \tan(\theta\sin\theta'\right) = 2{\cdot}3^{\text{cm}}$$

If the grating is moved $\triangle z$ cm. parallel to itself to be equal to these increments $\triangle x$, at an angle $90° - \theta'$ to the grating,

$$2\triangle z = \triangle x\cos\theta$$

remembering that $\triangle x$ and $\triangle z$ are passed over twice.

Thus it is not surprising that so many cases were identified. It is also apparent that the air compensations are very different and hence identification is facilitated. Finally, since a vertical slit and collimator are used, the section of a beam of light passing through the grating by a horizontal plane consists of parallel rays; the section by a vertical plane, however, is convergent.

It is interesting to find the numerical data for the above equations, assuming that $i = 45°$, $\theta' = 32° 39'$, $e = {\cdot}68^{\text{cm}}$, $\mu = 1{\cdot}53$ (estimated), $\lambda/D = {\cdot}1677$, for the sodium line of the spectrum. The results are given with the equations. Their mean value is about $2{\cdot}3^{\text{cm}}$, which is equivalent to a displacement of grating $\triangle z = {\cdot}6^{\text{cm}}$, the value actually found.

It follows, moreover, that the center of the ring system order, $n = 0$, must move from red to violet or the reverse, inasmuch as the compensation takes successively, at each color, in the same way. Although the equations hold only for the center and the symmetrically oblique rays belonging to the rings have not been given consideration, an approximate computation of the motion of the ring centers may nevertheless be attempted. The relations numbers 1, 3, 9, and 10, which are more important, may be taken. Here is n in the order of the fringe, D the grating space, $2x$ the difference of air path,

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* A glass plate with identical gratings on both sides is here in question.

$$2e\mu / \cos\theta + 2x = n\lambda\,;$$

this with

$$\sin i - \sin\theta' = \lambda / D,\ \sin\theta' = \mu\sin\theta,\ d\mu / d\lambda = -\cdot 015\,\mu / \lambda,$$

an experimental interpolation equation for the given glass, will on differentiation yield dz/dn, dz/de, $dz/d\lambda$, etc. From these qualitative interpretation of the above and the following data is obtainable; but quantitatively they are too crude, because they ignore the essential feature of oblique reflection from M and N. For the radial motion, if dz/dn is the displacement of grating normal to itself per fringe,

$$\frac{dz}{dn} = \frac{\lambda\cos\theta}{4}$$

is near the truth.

Omitting these equations, an example of the displacement and radial motion in a given experiment may be adduced; the former were fully 16 times less sensitive per fringe than the latter. The displacement is thus a coarse adjustment in comparison with the usual radial motion of the fringes and this is the distinct advantage of the present method for many purposes. It is like a scale division into smaller and larger parts, where the enumeration of small parts alone would be confusing or impossible. The ratio of the micrometer value of displacement and radial motion per fringe may be given any value since $dz/d\lambda \propto \mu e$. Thus $e = \cdot 42^{\mathrm{cm}}$ would correspond (for the same μ) to 10 radial fringes for one displacement fringe. Again if $e = \cdot 04^{\mathrm{cm}}$ the two micrometers would be equally sensitive. Or for $e = \cdot 01^{\mathrm{cm}}$ (microscope cover glass), the lateral displacement is actually four times more sensitive than the radial motion.

The sodium lines here make admirable cross hairs and the ocular itself need have none. The conditions are the same in the second order, and the coarser rings and spectrum lines are often easier to count.

4. *Compensator*—It is not necessary, however, to use thin glass, for if a compensator is provided, i. e., if the grating is on the common plane between two thicknesses of identical

plane-parallel glass plates, one of which carries the grating, the ideal plane in question is provided. The ellipses in this case would be infinite in size and their displacements infinitely large. By partial compensation (compensator thinner) ellipses of any convenient size and rate of displacement may therefore be provided at pleasure. The following table gives some rough experimental data where z is the advance of the micrometer screw normal to the grating, i. e., the displacement of the grating to move the center of fringes from the D to the b lines of the spectrum, e' the thickness of the compensator plate parallel to the mirror M or N as stated.

Displacement of ellipses from the D to the b line, by moving the grating Δz cm. normal to itself. $i=45°$, nearly. Grating: $e=·68$ cm.: $D = ·000,351$ cm.; $\mu = 1·53$ (estimated). Compensation shown by negative sign. Position p taken while the sodium line was the major axis.

Compensator thickness e'x10^2	Position of grating p	Micrometer displacement Δzx10^4	No of fringes D to b	Displacement per fringe 10^4xdz/dn	Ellipses	Side of compensator
cm.	cm.	cm.		cm.		
—48	·05	30	12	2·5	Very large	N
—44	·08	35	....	....	do.	N
—29	·12	45	....	....	Large	N
—10	·20	65	....	....	Mean	N
+48	·38	115	44	2·6	Very small	M
—65	·00	10	4·5	2·3	Enormous	N
± 0	....	70	28	2·5	Mean	None

Rotation of the compensator offers the usual easy method of adjustment. In the second order the first rings, on compensation, usually more than fill the field. This is of course eventually the case in the first order also. With very perfect compensation the ellipses are quite eccentric and the opposed lines nearly vertical and straight. Hence their motion, partaking of the twofold character specified, is complicated but usually opposite in direction on the two sides of the center for the same micrometer displacement. The whole phenomenon may vanish within a half mm. of play of the grating, passing from fine lines through enormous ellipses back into reversed fine lines, all nearly vertical.

The displacement of the grating by the micrometer screw is the same per fringe, no matter whether the ellipses are large or small, and in the last table it was about $\cdot 00025^{cm}$ per fringe. The displacement at the mirror would be more than twice this. The radial motion per fringe is of the order of wave-length. Naturally the position p of the grating changes parallel to itself linearly with the thickness e' of the compensator, supposing other conditions the same, so that p, z, and dz/dn all vary linearly with e', the thickness of the compensator. Finally, the virtual thickness of the air film can only be brought to vanish by compensation, otherwise spectra if equidistant are unequal in length from red to violet, and vice versa.

The full equations for the amounts of displacement, etc., requires an evaluation of $d\theta/dn$, which in turn must take into consideration that reflection from the mirrors cannot in general be normal, except for the one color instanced above. This investigation will have to be reserved for another communication.

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Art. XVI.—*Fox Hills Sandstone and Lance Formation ("Ceratops Beds") in South Dakota, North Dakota and Eastern Wyoming*;* by Timothy W. Stanton.

The Laramie question is a perennial problem for stratigraphers and paleontologists, but with the continued rapid accumulation of facts, as the detailed investigation of the stratigraphy is carried over the entire area involved, it is reasonable to hope that the problem will not be perpetual.

At the present time one of the most important points at issue is the relationship of the Lance formation† ("Ceratops beds") to the Laramie formation and to the conformable Cretaceous sequence beneath the Laramie. Some geologists hold that the Lance formation wherever it has been studied rests unconformably on the Laramie or some older formation and that the unconformity beneath it represents a long, complex epoch of elevation and erosion. In this paper evidence will be presented to show that in the rather widely distributed areas discussed there is a real transition from the marine Cretaceous Fox Hills sandstone into the Lance formation and that sedimentation was practically continuous from the one into the other and probably on through the Fort Union.

The data to be discussed were obtained in three areas mostly during the summer of 1909. One of these, which includes the Cheyenne River and Standing Rock Indian Reservations in northern South Dakota and southern North Dakota just west of the Missouri River, was examined for coal lands by Messrs. A. L. Beekly, Max Pishel and V. H. Barnett under the general supervision of Mr. W. R. Calvert. This investigation afforded an excellent opportunity for the study of the Fox Hills sandstone in its typical area and of its relations with the overlying Lance formation. A second area, which has been described in some detail by Prof. A. G. Leonard, is along the Little Missouri from Marmarth to Yule in the southwest corner of North Dakota, where I spent five days. The third area is the well known Lance Creek region in Converse County, eastern Wyoming, where Hatcher made his great collection of the Triceratops fauna. Nearly a week was spent here in company with Messrs. M. R. Campbell and R. W.

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* Published by permission of the Director of the U. S. Geological Survey.

† The name Lance formation has recently been adopted by the United States Geological Survey for the "Ceratops beds" of eastern Wyoming and adjacent areas. It is an abbreviated form of the term "Lance Creek beds" which J. B. Hatcher applied to these deposits in 1903 (American Geologist, vol. xxxi, p. 369) with the statement that the name is taken "from the principal stream in the region where they are best represented in Converse County, Wyoming."

Stone. The three areas, though separated by intervals of 100 to 150 miles, all belong to the same general region, throughout which it is evident that closely similar conditions prevailed in the closing stages of the Cretaceous.

Standing Rock and Cheyenne River Indian Reservations.

A detailed description of this area will be given by Mr. Calvert and his assistants in a report which is in preparation. For the present purpose it is only necessary to direct attention to a few points. The area lies on the west side of the Missouri River between Cheyenne River on the south and Cannonball River on the north and it is divided into three approximately equal parts by Moreau and Grand Rivers, tributaries to the Missouri from the west.

The rocks are little disturbed and usually appear horizontal in ordinary exposures, but a more general study of their distribution shows that they dip a few feet in the mile toward the north or northwest. The lowest formation exposed is the Pierre shale, the upper part of which is seen in the valleys of all the streams mentioned except the Cannonball. Above the Pierre is the Fox Hills sandstone in many places forming bluffs for long distances along the streams. This is the highest marine Cretaceous formation in the section. It extends up the Missouri as far as old Fort Rice, North Dakota, a few miles above the Cannonball, and underlies the higher ground in a broad belt of country southwest of that point. Overlying the Fox Hills sandstone is the less resistant non-marine Lance formation which in published reports has been called "Ceratops beds," "Laramie," "lower Fort Union" and "somber beds." It frequently forms badlands in the inter-stream areas on the reservations and extends up the Missouri valley to Bismarck and beyond. As the streams have cut through both the Lance formation and the Fox Hills sandstone for long distances, the relations between the two formations are easily studied.

The Fox Hills sandstone was first named by Meek and Hayden* in 1861, who stated that it "is most distinctly marked at Fox Hills, between Cheyenne and Moreau Rivers, above Fort Pierre." In the words of their description "this formation is generally more arenaceous than the Fort Pierre group, and also differs in presenting a more yellowish or ferruginous tinge. Towards the base it consists of sandy clays, but as we ascend to the higher beds, we find the arenaceous matter increasing, so that at some places the whole passes into a sandstone. It is not separated by any strongly defined line of demarcation from the formation below, the change from the fine clays of the latter to the more sandy material above being usually very gradual. Nor are these two formations distinguished by any abrupt change in the organic remains, since several of the fossils occurring in the upper beds of the Fort Pierre group pass up into the Fox Hills beds, while at some localities we find a complete mingling in the same bed of the forms usually found at these two horizons." The total thickness of the formation was then estimated at 500 feet, but in previous papers dealing with only the typical area the thickness was given as 100 to 150 feet, an estimate which is nearer the truth for this particular area.

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* Proc. Acad. Nat. Sci. Phila., vol. xiii, pp. 419, 427.

The variable character of the formation is indicated by Meek and Hayden's description just quoted and this variability as to details becomes impressive after a number of local sections have been examined. In some exposures nearly the whole formation is a soft, friable, cross-bedded gray or yellowish sandstone, usually with many iron-stained concretions and indurated masses as on Cannonball River, 6 miles above its mouth, where single exposures show 60 feet of sandstone and the base of the formation is not seen. At other places similar sandstones occur at the top and at the bottom and include indurated beds of considerable extent, while the middle portion of the formation is made up of more or less sandy shale in bands a few inches thick of alternating lighter and darker color. This banded shale contains considerable vegetable matter in the form of stems and comminuted fragments and in general lithologic character it closely resembles some parts of the overlying Lance formation. At still other localities within short distances either the upper sandstone or the lower one or sometimes both of them are found to thin or disappear as distinct beds, their places being taken by more shaly material. The whole formation gives ample evidence of irregular sedimentation in the presence of strong, variable currents.

The irregular character of the formation may be shown by describing a few local sections beginning on Grand River near the mouth of Dirt Lodge Creek about 20 miles southwest of McIntosh, South Dakota. On the south side of the river the following section is exposed:

Section on Grand River near the mouth of Dirt Lodge Creek.

	Feet
1. Hard gray sandstone with *Tancredia americana* and Halymenites	15
2. Banded shale with *Fasciolaria scarboroughi*, Thracia, Anchura, Scaphites, etc.	50
3. Hard gray sandstone with *Tancredia americana* and Halymenites	10
4. Soft yellowish massive sandstone	40
5. Dark clay shale referred to the Pierre, exposed	75

All except the basal member of the section belong to the Fox Hills.

The hard sandstones of Nos. 1 and 3 are merely local indurations which in some places are seen to pass horizontally into soft friable sandstone. Other exposures in the neighborhood especially on the north side of Grand River show that the upper sandstone, No. 1, is very near the top of the Fox Hills. About a mile northwest of the mouth of Dirt Lodge Creek and not more than two or three miles from the section just described the upper sandstone is represented by a few feet of sandy shale which pass upward into similar sandy shale about 4 feet thick, which is filled with brackish-water fossils including *Ostrea glabra* M. & H., *O. subtrigonalis* E. & S., *Anomia micronema* Meek, and *Corbicula subelliptica* var. *moreauensis* M. & H. Immediately above this brackish-water bed without any apparent stratigraphic break are shales, soft sandstones and carbonaceous beds, weathering into badlands, and locally containing abundant remains of Triceratops, Trachodon, turtles and other members of the Lance formation fauna.

About 3 miles east of the mouth of Dirt Lodge Creek in section 12, T. 20 N., R. 22 E., the oyster bed at the top of the Fox Hills is again exposed with the basal portion of the Lance formation above it. Vertebrate fossils of the types just mentioned are here abundant about 30 or 40 feet above the oyster bed.

A few miles farther east on Grand River near the mouth of Fire-steel Creek the contact of the oyster bed with the underlying sandstone shows an irregular surface suggesting an unconformity, but facts to be recorded on subsequent pages will show that the oyster bed actually belongs to the Fox Hills sandstone as proved by its fauna.

Another instructive section in T. 15 N., R. 18 E., on Thunder Butte Creek about 30 miles south of Grand River, is as follows:

Section on Thunder Butte Creek.

	Feet
1. Friable gray and yellow sandstone with many large indurated masses locally containing an oyster bed with an abundant brackish-water fauna mingled with many specimens of marine Fox Hills species (see list on p. 180). Some evidence of channeling and erosion at base of oyster bed	20
2. Banded shale and shaly sandstone	50
3. Dark, somewhat sandy, shale referred to the Pierre with *Avicula linguiformis* E. & S., *Mactra warrenana* M. & H., etc. Exposed	30

In this section the sandstone forms relatively a small part of the Fox Hills and the absence of a prominent lower bed makes the base of the formation uncertain. The fossils from the underlying shale so far as it is exposed belong to the Fox Hills fauna. The oyster bed in the upper member of the section at one point is a conspicuous indurated very fossiliferous bed fully fifteen feet thick, but it thins abruptly within a few yards to two feet or less, the variation being due to the irregularity of its base. In other exposures less than ¼ mile distant its position is only marked by scattering brackish-water shells. The Lance formation is seen in neighboring higher exposures.

The exposures a few miles farther south in T. 14 N., R. 19 E., on the south side of Moreau River show a section similar to that last described, but they give a better contact with the overlying Lance formation.

Section on south side of Moreau River.

	Feet
1. Soft sandstone, sandy shale, and carbonaceous shale in alternating beds a few feet thick, forming the base of the Lance formation. Fossil plants at the top and associated with Unio in the lower 4 feet (Lot 5423. See list below),	40
2. Soft friable cross-bedded gray sandstone irregularly stratified with bands of darker sandy shale. Large concretions or indurated masses near the base contain Fox Hills species of Scaphites associated with Corbicula (No. 5969. See list on p. 180). The Corbicula occurs in abundance to the top of the bed	30 to 40
3. Banded shale with a few marine Fox Hills fossils	60
4. Dark, somewhat sandy, shale referred to the Pierre but containing a Fox Hills fauna. Exposed	50

The fossil plants collected in the lower 4 feet of the Lance formation at this place have been examined by Dr. F. H. Knowlton, who refers them to the Fort Union and identifies the following species:

5423. *Thuya interrupta* Newb.
Sequoia Nordenskiöldi Heer
Populus cuneata Newb.
Viburnum marginatum Lesq.
Sequoia acuminata?? Lesq.
Leguminosites? n. sp.
Cyperacites sp.
Monocotyledon—new

This list is given for the purpose of showing that the Fort Union flora ranges to the base of the Lance formation. All the other plant collections from this formation were likewise referred to the Fort Union.

The minimum thickness of sandstone in the Fox Hills of this region was seen in a section at Rattlesnake Butte near the northwest corner of T. 11 N., R. 19 E., about 15 miles south of Moreau River.

Section at Rattlesnake Butte, South Dakota.

		Feet
1.	Hard gray sandstone with *Glyptostrobus Ungeri* Heer, *Taxodium occidentale* Newb., *Viburnum marginatum* Lesq., *Cornus Newberryi* Hollick, and other plants referred to the "lower Fort Union"	25
2.	Clay shale	10
3.	Carbonaceous shale	4
4.	Clay shale with some carbonaceous bands	8
5.	Carbonaceous shale	7
6.	Soft, friable yellowish sandstone with large concretions or indurated masses in the upper part, forming top of Fox Hills	12
7.	Banded shale with a few marine Fox Hills shells	90

This is the base of the local exposure, but in the neighborhood dark shale referred to Pierre is seen not many feet lower. The upper 5 members evidently belong to the Lance formation. No. 6 did not yield any fossils at this point, but on Mud Butte, about 5 miles south, the same horizon yielded the mixture of brackish-water and marine Fox Hills species listed as No. 5870 on p. 179.

It is evident from these sections that the Fox Hills sandstone is variable throughout its thickness. The lower part is no more constant than the upper. Its base is therefore indefinite, and it is by no means certain that the top of the dark shale necessarily taken as the top of the Pierre in the different sections represents exactly the same geologic horizon. The fauna of at least the upper 100 feet of Pierre shale is essentially a Fox Hills fauna, indicating shallow marine waters and differs very little from that of the overlying sandstone, while it lacks all the species which in other areas are especially characteristic of the Pierre.

The most common and characteristic species of this fauna in the Fox Hills sandstone and the upper part of the Pierre shale are as follows:

Avicula linguiformis E. & S.
Avicula nebrascana E. & S.
Cucullæa shumardi M. & H.
Limopsis striatopunctata E. & S.
Leda (*Yoldia*) *evansi* M. & H.
Nucula cancellata M. & H.
Nucula planimarginata M. & H.

Lucina occidentalis (Morton)
Tancredi americana M. & H.
Protocardia subquadrata E. & S.
Callista deweyi M. & H.
Tellina scitula M. & H.
Mactra warrenana M. & H.
Cuspidaria ventricosa (M. & H.)
Lunatia occidentalis M. & H.
Lunatia concinna H. & M.
Lunatia subcrassa M. & H.
Anchura (*Drepanochilus*) *americana* (E. & S.)
Pyropsis bairdi M. & H.
Fasciolaria (*Piestochilus*) *culbertsoni* M. & H.
Fasciolaria buccinoides M. & H.
Pyrifusus newberryi M. & H.
Fusus (*Serrifusus*) *dakotensis* M. & H.
Cylichna volvaria M. & H.
Haminea minor M. & H.
Cinulia concinna M. & H.
Sphenodiscus lenticularis (Owen)
Scaphites conradi (Morton)
Scaphites conradi var. *intermedius* Meek
Scaphites abyssinus (Morton)
Scaphites nicolleti (Morton)
Scaphites cheyennensis (Owen)

At some localities as on Grand River near Dirt Lodge Creek the sandstones are filled with *Tancredia americana* M. & H., with very few other species.

At the top of the Fox Hills sandstone with its purely marine fauna there is a rather thin but widely distributed brackish-water bed, already several times referred to, which contains Ostrea, Anomia, Corbicula, Melania, etc., in great abundance. The zone in which this fauna occurs varies in thickness from 3 or 4 feet up to 40 feet and is lithologically very similar to the underlying marine beds, but its base is irregular at many places and shows channeling and other evidence of erosion. It was therefore regarded by the field geologists as the basal member of the overlying Lance formation resting unconformably on the Fox Hills. In the study of this brackish-water bed evidence was found at several localities, distributed over a considerable area, that there is a distinct transition without a break of any importance between the marine Fox Hills sandstone and the brackish-water deposit. The paleontologic evidence consists of distinctive Fox Hills species belonging to such marine genera as Scaphites, Lunatia, and Tancredia, found directly associated in the same bed with the brackish-water forms and occurring with them in such a way that they must have lived together or near each other and been imbedded at the same time. Such a mixture of faunas was found at five localities, as shown in the following lists. The marine Fox Hills species are marked with an *.

5870. Mud Butte, SW 1/4 Sec. 25, T. 11 N., R. 18 E., about 20 miles south of Moreau River.

Ostrea subtrigonalis E. & S.
Ostrea glabra M. & H.
Anomia micronema Meek
Modiola meeki (E. & S.) ?
Corbicula occidentalis M. & H.
Corbicula cytheriformis M. & H.
Corbicula subelliptica var. *moreauensis* M. & H.
Panopœa? sp.
* *Teredo* sp.
Neritina bruneri White
Neritina (*Velatella*) *baptista* White
Melania insculpta Meek var.
Melania wyomingensis Meek
Viviparus sp.
Melampus sp.
* *Scaphites conradi* (Morton)

The stratigraphic relations at this locality have been described in connection with the Rattlesnake Butte section on p. 177.

5871. Sec. 2, T. 11 N., R. 19 E., about 4 miles south of Moreau River.

Ostrea subtrigonalis E. & S.
Anomia micronema Meek
Corbicula subelliptica var. *moreauensis* M. & H.
* *Lunatia concinna* H. & M.

Mr. Barnett reports that the fossils were obtained from a small exposure of friable sandstone in which the fossiliferous band is two feet thick.

5938. SE 1/4 SW 1/4 Sec. 18, T. 17 N., R. 26 E.

Ostrea glabra M. & H.
Anomia sp.
Corbicula occidentalis M. & H.
* *Tancredia?* n. sp.
Melania insculpta Meek
* *Scaphites conradi* (Morton)

Mr. Barnett states that the fossiliferous bed is an indurated sandstone about 40 feet thick at the top of the Fox Hills.

5969. Sec. 27, T. 14 N., R. 19 E. South side of Moreau River, above Thunder Butte P. O.

Corbicula nebrascensis M. & H.
Melania insculpta Meek
* *Scaphites conradi* var. *intermedius* Meek
* *Scaphites cheyennensis* (Owen)

The section in which this collection was obtained is described on p. 176.

5975. North side of Thunder Butte Creek near south line Sec. 12, T. 15 N., R. 18 E.

Ostrea glabra M. & H.
Anomia micronema Meek
Corbicula occidentalis M. & H.
Corbicula cytheriformis M. & H.
Corbicula subelliptica var. *moreauensis* M. & H.
* *Tancredia americana* M. & H.
* *Tancredia?* n. sp.
* *Lunatia subcrassa* M. & H.?
Melampus sp.
Melania wyomingensis Meek
Melania insculpta Meek
* *Scaphites conradi* (Morton)

The section at this locality is described on p. 175.

The brackish-water species elsewhere are found in the Laramie and in the non-marine formations of the Montana group, but the marine forms, especially the ammonoids, which give the best evidence as to age, belong to the Fox Hills fauna. It is clear from these occurrences that there was no erosion interval of any geological importance between the marine Fox Hills and the overlying brackish-water bed, and that the latter belongs to the Fox Hills epoch of sedimentation.

Above the brackish-water horizon is the fresh-water Lance formation consisting of soft sandstones, shales, thin coals and carbonaceous shales, retaining the same general character through 500 or 600 feet of strata. The flora from these beds, ranging from the bottom to the top, is referred by Dr. Knowlton to the Fort Union. Vertebrate fossils are common, especially in the lower 100 feet and ranging down to the base. These include the dinosaurs Triceratops and Trachodon with several other genera that are characteristic of the Lance formation fauna elsewhere.

The history of the epoch immediately following the Fox Hills sedimentation in this region has received two very different interpretations. One is the view here presented, that without any unrepresented interval of importance there was gradual transition from marine conditions through brackish-waters to the land and fresh-water conditions that generally prevailed during the deposition of the Lance formation. The other adopts the current interpretation of the evidence from fossil plants which refers the Lance formation to the Fort Union formation, assigned to the Eocene, and requires a period between the close of the Fox Hills and the beginning of the Lance formation long enough to represent the Laramie, Arapahoe, and Denver formations of the Denver Basin, together with the long intervals of erosion which preceded the Arapahoe and the Denver, and another interval supposed to be between the Denver and the Fort Union. It has been asserted that the erosion preceding Arapahoe deposition cut down through 14,000 feet of stratified rocks in the Denver area. It is worthy of note that there are no Fort Union rocks or floras known in the Denver Basin and no plant-bearing formations older than the Lance formation in the area now under discussion.

Early in their field work last summer the geologists had determined that the Lance formation immediately overlies the Fox Hills, and had received reports that the plants from near their base belong to the Fort Union flora. Special search was therefore made for physical evidence of the unconformity and hiatus which the facts seemed to demand. The only horizon at which a somewhat generally distributed break was suggested is at the irregular base of the brackish-water bed, and this irregular surface was therefore tentatively taken as the base of the Lance formation on the supposition that it indicated a hiatus in the sedimentary record equivalent to the Laramie and post-Laramie formations of the Denver Basin. That there was no such break in the record at this horizon is definitely proved by the occurrence of ammonoids and other fossils characteristic of the marine Fox Hills in the brackish-water bed as already described. The brackish-water fossils in themselves give evidence of their Cretaceous age. In the first place, almost all of them belong to species that in other areas occur in unquestioned Cretaceous formations. Secondly, brackish waters with such a fauna as the one in question must have had connection with the sea and no connection with Tertiary seas is probable. Marine waters retreated from the region of the Rocky Mountains and Great Plains at or just before the close of the Cretaceous, and there is no evidence that the sea has approached the region since that time. The nearest marine deposits of Eocene or later age are in the lower Mississippi valley and in the Gulf coastal plain of Texas. This fact gives special importance to the occurrence of an oyster bed 500 feet above the base of the Lance formation on the Little Missouri River, North Dakota, which will be described on a subsequent page.

It may be suggested that there is a stratigraphic break between the brackish-water and fresh-water horizons, but no evidence of such a break has been found there. It is true that at various levels throughout the Lance formation there is evidence of current action and irregular deposition shown in cross-bedding, varying thickness and uneven surfaces of sandstones, and similar phenomena. Such features are characteristic of continental deposits, and have little weight as evidence of important unconformities unless supported by other lines of evidence. In this case all the irregularities observed seem to be of purely local character.

Valley of the Little Missouri from Marmarth to Yule, North Dakota.

In the southwest corner of North Dakota, near the town of Marmarth on the Chicago, Milwaukee & Puget Sound Railway, the valley of the Little Missouri cuts down through the Lance formation and the Fox Hills into the Pierre, and shows a section comparable with those in the Indian reservations which we have been discussing. The area has been described by Prof. A. G. Leonard,* and my observations added little to the facts he has recorded.

The Pierre shale is exposed on Little Beaver Creek, about 5 miles southwest of Marmarth, and yields a typical Pierre fauna with less admixture of Fox Hills species than is found in the top of the Pierre in the reservations.

Immediately above the Pierre shale is banded shale with a thickness of about 40 feet overlain by 40 feet of soft massive sandstone, yellow with iron-stained bands and concretions below, grading up into gray sandstone above. This sandstone yielded a few marine fossils, including *Leda* (*Yoldia*) *evansi*, *Tellina scitula*, *Entalis? paupercula* and *Halymenites major*, which confirm Leonard's reference of the sandstone to the Fox Hills. In several bluff exposures along the creek the top of the gray sandstone shows an uneven eroded surface which Professor Leonard has photographed and described† as an unconformity in the following words: "It is well shown at two points on Little Beaver Creek in section 7, T. 132 N., R. 106 W. Here the massive sandstone forming the top of the Fox Hills is seen to have undergone erosion before the deposition of the brown and black highly carbonaceous and argillaceous sandstone, which shows cross-limitation in places. Some of the depressions of the former land surface have been eroded to a depth of 6 feet below the adjoining elevations." Immediately above this eroded surface is the Lance formation, which Professor Leonard has described as "somber beds" and "lower Fort Union," with an estimated thickness of about 600 feet extending northward down the river 15 or 20 miles to the neighborhood of Yule P. O. There is a very slight northward dip. Beds of carbonaceous shale and impure lignites are distributed throughout the formation beginning with the basal stratum, and in the upper half, according to Leonard, there are 5 or 6 workable coal beds. Dinosaur remains, including Triceratops and Trachodon, are not uncommon in the lower part, especially in the badlands near the mouth of Bacon Creek, a mile northeast of Marmarth. The formation is in every particular similar to the equivalent Lance formation in the Cheyenne River and Standing Rock reservations.

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* 5th Bienn. Rept. N. Dak. Geol. Surv., 1908, pp. 29–114.

† Op. cit., pl. v, p. 72.

Irregular deposition and erosion with deep channeling are strikingly exhibited at several localities and on different horizons. One example of erosion which is worthy of description in a separate article is clearly shown in a cut bank by the side of the railroad yard at Marmarth, probably less than 100 feet above the base of the Lance formation. A bed of carbonaceous shale with an average thickness of 20 feet is exposed to its full length of 250 feet. Both the top and the bottom surfaces are irregular as if eroded, and the underlying sandstone and the argillaceous bands in the bed are filled with vertical roots of plants. One end of the bed fingers out into cross-bedded sand while the other end is abruptly truncated and abuts against a friable, cross-bedded yellowish gray sandstone similar to and continuous with the sand that overlies the carbonaceous bed. Here is evidence of erosion at the base of the carbonaceous bed apparently as great as that at the base of the whole formation, and of still greater erosion at the top of the same bed.

It will be noticed that in this area there is no brackish-water bed at the top of the Fox Hills. Instead the change is abrupt from marine to land or fresh-water deposits, but there is evidence that marine or at least brackish-water conditions continued in a neighboring area for some time after non-marine deposition began. Professor Leonard reported the finding of an oyster bed in the upper part of the "somber beds" about five miles southwest of Yule in sect. 16, T. 135 N., R. 105 W., which is only about 15 miles north of Marmarth. The locality was visited last summer and the oysters were found associated with a coal (apparently bed F of Leonard's section*) about 175 feet above the river level and according to Leonard's estimates approximately 500 feet above the base of the Lance formation and certainly above all the dinosaurs that have been found in the region. The abundant oysters referable to *Ostrea subtrigonalis* and *Ostrea glabra* lie a few feet above the coal in a carbonaceous shale. In some places the shells form a nearly solid band 6 inches thick, and they are distributed in thin bands and scattered individuals through 7 feet of shale. Such an oyster bed must have been formed in tidal waters connected with the sea, and its presence here argues strongly for the assumption that the underlying portion of the Lance formation was formed near sea level so that a slight downward movement permitted local temporary admission of brackish water into the low lying swamps and marshes in which coal was forming. It is, therefore, most probable that the abrupt change from marine to fresh-water and land conditions seen near Marmarth is purely local, and that the eroded surface at the top of the Fox Hills does not represent a time interval of any geologic importance.

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* 5th Bienn. Rept. N. Dak. Geol. Surv., 1908, p. 78.

Lance Creek Area, Converse County, Wyoming.

This well-known area has been described by Hatcher[*] and by Stanton and Knowlton,[†] and has recently been further discussed by Knowlton[‡] and Stanton.[§] In the examination of last summer special attention was given to the Fox Hills sandstone and its relation with the basal portion of the Lance formation. Our principal contribution to the knowledge of the stratigraphy of the area was the discovery that the marine Fox Hills deposits extend about 400 feet higher than had previously been determined, and that non-marine coal-forming conditions were temporarily inaugurated here before the close of Fox Hills time.

The first section examined is on the south side of Cheyenne River at the mouth of Lance Creek, and extending up the creek a mile and a half or two miles. Beginning at the top of a prominent white sandstone the section is as follows:

		Feet
1.	White cross-bedded sandstone with irregular brown indurated bands, masses, and concretions	50
2.	Soft sandy shale with bands of lignitic shale. Fragments of dinosaur bone were found on the surface here	50
3.	Sandy shale full of *Corbicula cytheriformis?* and *Corbicula subelliptica* var. *moreauensis*	1/2–1
4.	More or less carbonaceous shale	15
5.	Soft massive gray sandstone with many brown concretions	25
6.	Gray sandstone and sandy shale with bands of sandstone containing Fox Hills fossils, about	150
7.	Cross-bedded, ripple marked, reddish brown sandstone with irregular base	8 to 10
8.	Massive soft buff sandstone with many large concretions and indurated masses and an abundant Fox Hills fauna	100
9.	Pierre shale with only the top exposed	

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[*] This Journal (3), vol. xlv, pp. 135–144, 1893. Am. Naturalist, vol. xxx, pp. 112–120, 1896.
[†] Bull. Geol. Soc. Am., vol. viii, pp. 128–137, 1897.
[‡] Proc. Washington Acad. Sci., vol. xi, pp. 179–238, 1909.
[§] Ibid., pp. 239-293.

The following is the list of fossils collected in No. 8 of this section:

Avicula fibrosa M. & H.
Leda (*Yoldia*) sp.
Sphæriola? cordata M. & H.
Veniella humilis M. & H.
Protocardia subquadrata E. & S.
Linearia? formosa M. & H.
Tellina scitula M. & H.
Cuspidaria moreauensis (M. & H.)
Entalis paupercula M. & H.?
Lunatia occidentalis M. & H.
Anchura sp.
Fasciolaria (*Piestochilus*) *culbertsoni* M. & H.
Haminea sp.
Sphenodiscus lenticularis (Owen)
Scaphites conradi (Morton)
Scaphites conradi var. *intermedius* Meek.
Scaphites abyssinus (Morton).

No. 6 yielded the following:

Nucula planimarginata M. & H.
Avicula fibrosa M. & H.
Cardium speciosum M. & H.
Mactra warrenana M. & H.

When studying the section it was believed that the upper four members belong to the Lance formation, but afterward when comparison was made with sections at the south end of the field it seemed more probable that all the beds examined here belong to the Fox Hills. The higher unquestioned Lance formation was not studied at this place.

Two sections, which have been described by Stanton and Knowlton, were studied at the south end of the area, about 30 miles southwest of the mouth of Lance Creek. One of these lies about 2 miles east of Lance Creek, nearly opposite the mouth of Little Lightning Creek, and shows excellent exposures of Pierre, Fox Hills, and the lower part of the Lance formation, all dipping northward 14° to 19°. No attempt was made to obtain a detailed section of the Lance formation, but a measurement across the strike as far as the strata have steep dips shows a thickness of about 1700 feet above the upper white sandstone, which was later determined to be the top of the Fox Hills. To this should be added perhaps 400 or 500 feet for the thickness of the nearly horizontal upper strata of the Lance formation. The lowest point at which dinosaur bones were seen is about 300 feet above the top of the Fox Hills.

The lower part of the section is as follows:

Section on divide between Lightning and Buck Creeks.

		Feet
1.	Gray sandstone	10
2.	Shale	25
3.	Sandstone and shale	20
4.	Shale and coal	15
5.	Shale with brackish-water fauna	20

Top of Fox Hills.

6.	Massive white sandstone with brown concretions	40
7.	Shaly sandstone	5
8.	Coal and carbonaceous shale	15
9.	Massive white sandstone	60
10.	Shale	8
11.	Sandstone	10
12.	Shale	5
13.	Massive white sandstone	100
14.	Brownish gray sandstone in alternations of massive and more thinly bedded	130
15.	Gray sandstone	30
16.	Brown sandstone	20
17.	Yellowish sandstone with Fox Hills fauna	30
18.	Pierre shale	

The last section examined and perhaps the best exposed and most instructive of all is on Johnson Brothers' ranch, near Buck Creek, about 8 miles east of the section just described. Beginning with the lowest strata of the Lance formation the section follows:

Section on Buck Creek.

		Feet
1.	Sandy shale with thin beds of coal	25

Top of Fox Hills.

2.	Massive white sandstone with *Halymenites major*	60
3.	Yellowish massive sandstone with brown concretions	20
4.	More thinly bedded brown sandstone with *Halymenites*	25
5.	Massive white sandstone	75
6.	Soft somewhat sandy shales with thin sandstone bands containing marine Fox Hills shells	30
7.	Brown shaly sandstone	5
8.	Massive white sandstone	60
9.	Thin-bedded brown and gray sandstone	130
10.	Yellowish massive sandstone with concretions containing Fox Hills fauna	100
11.	Pierre shale	

The list of fossils from No. 6 is as follows:

Avicula nebrascana E. & S.
Avicula fibrosa M. & H.
Leda? sp.
Nucula planimarginata M. & H.
Tellina scitula M. & H.
Lamna? sp.

The occurrence of these fossils in No. 6 and of *Halymenites* at higher horizons shows that the strata to the top of the white sandstones are mainly marine and belong to the Fox Hills. In previous descriptions, only No. 10 was referred to the Fox Hills and the age of the overlying 400 feet of sandstones was left doubtful.

In the Lance Creek area the evidence for a gradual transition from the marine Fox Hills into the Lance formation is found in the occurrence of a brackish-water bed at the top of the marine strata, in the presence of coal beds and other evidence of alternating land and marine conditions before the close of the Fox Hills, and in the absence of any indication of an important unconformity anywhere in the section.

As compared with sections in the other areas here discussed the most striking feature of the Converse County sections is the much greater thickness of the Fox Hills sandstone and of the Lance formation. The average thickness of the Fox Hills sandstone in the South Dakota sections described is little more than 100 feet and it is still less at Marmarth, North Dakota, while in Converse County it is 400 to 500 feet, making the ratio about 1 to 4. The Lance formation shows about the same ratio of increase and the marine Cretaceous formations beneath the Fox Hills are also known to be much thicker in Converse County. Farther south in Colorado these marine formations, including the Fox Hills, show a still greater increase in thickness. It is therefore reasonable to attribute the variation in the thickness of the Fox Hills to variation in the rate of sedimentation due to varying distances from the source of supply and perhaps to variation in the height of the neighboring lands. That the varying thickness is not due to erosion from the top is proved in the case of some of the thinnest sections by the presence of the brackish-water beds at the top showing the final stage in marine sedimentation.

The three areas discussed in this paper taken together tell a story of gradually changing conditions near the end of the Cretaceous when the uplift of the Rocky Mountain region was draining the interior sea. The uplift was not uniform nor continuous and the emergence above sea level could not have been simultaneous for all localities throughout the region. As the sea became shallow the effect of tidal currents and wave action was shown in irregular deposition, cross-bedding and local erosion, and when an area was elevated above tide the deposits formed were subjected to all the varying conditions of flood plains, deltas and marshes. It would depend on the configuration of the coast, the topography and drainage of the adjacent land and the rate of elevation whether at any particular locality the last marine bed would be covered by a brackish-water deposit or followed immediately by land conditions. With such a history it is not surprising that the Fox Hills sandstone varies considerably in thickness and shows somewhat varying relations with the overlying formation.

The bearing which the facts here presented have on the Laramie problem is self-evident. If it is true that there is a transition with practically continuous sedimentation from the Fox Hills sandstone into the Lance formation in the region discussed, then the Lance formation includes or forms part of the Laramie.

ART. XVII.—*A New Occurrence of Hydrogiobertite*; by ROGER C. WELLS.

SOME specimens of an evaporation deposit which appear to consist chiefly of hydrogiobertite were recently examined in the chemical laboratory of the United States Geological Survey. These specimens were collected by Mr. G. A. Waring of the Survey in Chiles Valley, Napa Co., California, near Phillips Springs. The deposit occurs in considerable quantities below the springs and rests upon and penetrates a friable shale. In the vicinity above the springs are serpentinized rocks which may have been the source of the magnesium. In one specimen the incrustation covers fossil wood; in other specimens the surface of the shale is covered by spherulitic growths of 1–2^{mm} diameter, while the interstices of the shale are completely filled with the deposit.

Examined under the microscope, the spherules are seen to possess a banded structure, and to contain small amounts of a white opaque substance. Under these circumstances, an exact optical characterization could not easily be made. The spherules are white externally, their broken surfaces grayish-brown. $G._{24^\circ} = 2{\cdot}152$ (Thoulet solution). H. = 3–4. Streak white. The substance effervesces with cold acid. Many of the spherules contain a particle of shale in the center.

Two samples of the incrustation were analyzed. The first, A, was powdered as submitted, including considerable shale; the second, B, a small portion, had been picked as free from the shale as possible. The results of two analyses of A and of B are given in the first three columns. In the next two columns are given the percentage of MgO, CO_2 and H_2O, reduced to 100 per cent after subtracting the CO_2 equivalent to the CaO found. In the last column is given the theoretical percentage for hydrogiobertite, $2MgO.CO_2.3H_2O$.

	A1	A2	B	Mean of A1 and A2	B	Theory
Insoluble	25·41	25·33	14·93			
$(Al,Fe)_2O_3$	1·85	1·90	1·06			
CaO	2·54	2·60	1·84			
MgO	....	31·81	36·40	46·94	45·80	44·9
CO_2	18·08	18·06	23·71	23·64	28·00	24·7
H_2O	19·81	20·06	20·81	29·42	26·20	30·4
		99·76	98·75	100·00	100·00	100.0

The original hydrogiobertite described by Scacchi was found in an igneous rock.[*] Later, a mineral provisionally designated hydrogiobertite was found on asbestos by Brugnatelli in the Val Brutta.* The same author subsequently examined a similar mineral more thoroughly and designated it artinite with the formula $MgCO_3.Mg(OH)_2.3H_2O$.† The deposit here described seems to agree better with the formula of hydrogiobertite than with that of any other hydrated basic carbonate of magnesium. The occurrence is remarkable for being a spring deposit. As might be expected under these conditions, the specimens are not very pure and vary considerably from point to point. The deposits are freely exposed to the weather and rain, which may partly account for their irregularity of growth and structure.

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[*] E. Scacchi, Rend. Accad. Sci. Napoli, Dec. 12, 1885.

U. S. Geological Survey, June 15, 1910.

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* Zs. Kryst., xxxi, 54, 1899.

† Zs. Kryst., xl, 103, 1905, xli, 257, 1906.

ART. XVIII.—*A New Occurrence of Plumbojarosite;* by W. F. HILLEBRAND and FRED. E. WRIGHT.

SOME months ago the senior author received from Prof. O. C. Farrington, of the Field Museum of Natural History, Chicago, a small sample of what was supposed to be jarosite. It had been received some years before from Dr. Merrill of the Utah School of Mines, who said that it came from American Fork, Utah. It formed friable lumps in association with pyromorphite and calcite for the most part. These two were easily removed by dilute nitric acid, and treatment with the Thoulet solution freed the mineral nearly completely from a further impurity of relatively low density. Analysis gave the following values for the constituents:

Fe_2O_3	42·87*	per cent.
PbO	18·46	"
K_2O	0·15	"
Na_2O	0·52	"
SO_3	27·67	"
H_2O	10·14	"
CuO	0·10	"
CaO	0·06	"
Insol.	0·40	"
	100·37	

* With a very little P_2O_5. Alumina probably absent.

The analysis had to be made in odd moments and is, therefore, not so satisfactory in all respects as could be wished, but the agreement with the analysis of plumbojarosite from Cook's Peak, New Mexico,† is most striking.

Crystallographic and Optical Properties.—The crystals are small and average about 0·15^{mm} in width and 0·05 to 0·1^{mm} in thickness. They occur in sharply bounded, equant hexagonal plates, limited by the basal pinacoid *c* (0001) and the unit rhombohedron *r* (10$\bar{1}$1). Under the microscope the minute crystals occasionally resemble in shape a spinel crystal resting on an octahedral face. Several of the crystals were measured on the two-circled goniometer with reducing attachment. For the adjustment the rhombohedral faces, and not the base, which invariably gave multiple reflection signals, were used. The angular values obtained varied slightly from crystal to crystal, but this was probably chiefly, if not wholly, due to the poor quality of reflection signals obtained. On one crystal 0·21^{mm} wide and 0·08^{mm} thick, the average of the angles ρ, or $c \wedge r$, for the three unit rhombohedral faces was 53° 41′, while on a second crystal a slightly lower average value, 53° 15′, was obtained. So far as can be judged from the measurements made, the most probably value is about 53° 40′, a value which may possibly be in error 20′–30′.* This value is a little lower than that obtained by Penfield† on plumbojarosite from Cook's Peak, New Mexico ($c:r=54° 30'$), and part of the difference may be due to difference in chemical composition, and part to uncertainty in angular measurements as a result of the imperfect development of the crystal faces. In habit, the crystals from Utah differ also slightly from those in New Mexico, the latter crystallizing in thin flakes, while the former, although tabular in shape, are much thicker and more nearly equant.

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† This Journal (4), xiv, 213–215, 1902.

In the aggregate the deep brownish red crystals glisten with almost adamantine luster. They are brittle and easily crushed, and in powder form give an ochre-colored streak. Evidences of fair cleavage after the unit rhombohedron $(10\bar{1}1)$ were observed.

Under the microscope the grains are pale golden yellow to brownish red in color and strongly pleochroic, $\mathfrak{c}$ being dark brownish red and $\mathfrak{a}$ pale golden yellow. Absorption strong $\mathfrak{c}>\mathfrak{a}$.

The refraction indices are high and were determined by the immersion method; ϵ is about 1·785 and $\omega>$ 1·825. The birefringence is strong and greater than ·040. In convergent polarized light, the crystals are uniaxial, optically negative, with strong birefringence. Occasionally a slight opening of the dark interference cross was observed but was not of sufficient regularity in its occurrence to be significant.

Washington, D. C.
July 1.

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* This angle $c:r$ was also determined by Dr. O. C. Farrington (letter of July 6, 1910). His measurements averaged 53° 30′, a value which agrees fairly well with the above.

† This Journal (4), xiv, 213-215, 1902.

Art. XIX.—*The Heat of Formation of the Oxides of Cobalt and Nickel; and sixth paper on the Heat of Combination of Acidic Oxides with Sodium Oxide;* by W. G. Mixter.

[Contributions from the Sheffield Chemical Laboratory of Yale University.]

Cobalt.

1. *Heat of combustion of cobalt*—The cobalt and its oxides used in the work were obtained from a cobalt carbonate of unknown source. It was probably made by precipitation with ammonium carbonate, as it contained ammonia. Metallic cobalt, which was reduced by hydrogen at about 420° and kept at this temperature for three hours and at a pressure of 65^{mm} of mercury and then left to cool, ignited spontaneously in the air. When the reduction was made at incipient redness, then lowering the temperature to 420° and reducing the pressure as above stated, the oxidation was less rapid in air. The metal reduced at 420° was dark grey and very bulky; that reduced at the higher temperature was lighter colored. Whether oxidation of the cobalt at common temperature was due to the finely divided state of the metal or to a content of hydrogen was not determined. The metal used for the calorimetric experiments was reduced at a cherry-red heat and cooled in hydrogen at atmospheric pressure. It probably oxidized slightly in the air. It was sifted through a 1/100 inch mesh. The method of determining the heat of oxidation of cobalt was as follows: The metal was spread over a flat, thin silver foil or mica tray 7 to 8^{cm} in diameter, which was fastened 3 to 6^{cm} above the bottom of the bomb. The bomb was exhausted and then filled with dry oxygen at a pressure of 12 to 13 atmospheres. In the upper half of the bomb was a fine iron wire which was ignited by an electric current. The hot globule of magnetic oxide falling on the cobalt ignited it. The tray, the oxide formed and the unoxidized cobalt were all melted. The oxide was found in the bottom of the bomb in the shape of a black crystalline hollow lump about 3^{cm} wide and 2^{cm} thick. The unburned metal was in one or more globules at the bottom of it. The observed weight of the solid contents of the lower half of the bomb less the weight of the tray, metal taken and Fe_3O_4 from the iron wire, plus 4·4 per cent correction for water and volatile matter in the mica, gave the weight of oxygen taken up in the combustion. After weighing, the lump above mentioned was broken and the globules of metallic cobalt separated and weighed. To make sure that the oxide was then free from particles of the metal it was pulverized and

stirred up in water with an electromagnet. The weight was noted of the metallic cobalt found in a fusion.

Experiment 1.—The platinum electrode in the bomb was a millimeter thick and was about 3^{cm} above the tray. The end of it melted off at the time of the combustion and dropped into the mass below and alloyed with the cobalt. Hence the gain in weight due to oxygen could not be found and, therefore, the oxide was reduced by hydrogen. The loss in oxygen was 2·747 grams. The calorimetric result, 9658^c ÷ 2·747 = 3480^c for 1 gram of oxygen taken up and for 16 grams 55,680^c.

Experiment 2.—This test was like the preceding except that a mica tray was used. It was placed lower in the bomb and farther from the platinum electrode, which, nevertheless, melted off. The cobalt oxide was reduced as before. The result for 16 grams of oxygen was 55·984^c.

Experiments	3	4	5
Cobalt	12·417 grams	13·027 grams	15·364 grams
Cobalt unburned	0·793 “	0·507 “	1·631 “
“ burned	11·624 “	12·520 “	13·733 “
Mica tray	0·417 “	0·497 “	0·268 “
Oxygen taken up	3·088 “	3·340 “	3·706 “
Water equivalent of system	3,467· “	3,535· “	3,617· “
Temperature interval	3·190°	3·396°	3·678°
Heat effect	11,060	12,005	13,303^c
“ of oxidation of iron	50	48	50^c
	11,010	11,957	13,253^c
For 1 gram of oxygen	3,565	3,580	3,576^c
“ 1 “ “ cobalt	947	955	966^c
“ 16 “ “ oxygen	57,040	57,280	57,216^c
“ 59 “ “ cobalt	55,873^c	56,345^c	56,994^c

Oxygen ratio $\frac{3·088}{16} = 0·193 \quad \frac{3·34}{16} = -0·209 \quad \frac{3·706}{16} = 0·232$

Cobalt ratio.. $\frac{11·624}{59} = 0·197 \quad \frac{12·52}{59} = 0·212 \quad \frac{13·733}{59} = 0·233$

In 3 all of the metallic cobalt left was in one globule. The oxide obtained in this experiment was pulverized in a steel mortar and the powder stirred up in water with an electromagnet which removed an insignificant quantity of black particles. Next, 2·8969 grams of the powdered oxide, dried at 100°, was reduced by hydrogen, and 2·2800 grams or 78·74 per cent of cobalt obtained. CoO contains 78·67 and Co_3O_4

73·44 per cent of cobalt. The cobalt was not quite pure, containing a little silicon and iron. The ratio of oxygen consumed to cobalt burned in experiments 3, 4, and 5 and the ratio found in the analysis given is very nearly 1 to 1, proving that the oxide is mostly CoO. Portions of oxide from the combustion were tested for a higher oxide by treating with hydrochloric acid. A small quantity of chlorine evolved indicated that the oxide contained a little Co_3O_4. Why then is not the ratio of oxygen to cobalt greater than 1 to 1 instead of slightly less? The presence of impurities accounts for it in the portion analyzed, and the fact that the oxygen ratios found in experiments 3, 4, and 5 are low, and also that the heat effect calculated for one gram atom of cobalt burned is less than found for one gram atom of oxygen taken up, prove that the cobalt used in the experiments was slightly oxidized. Moreover, the formation of a small amount of Co_3O_4 affects the result but slightly since, as shown later, $3CoO + O - Co_3O_4 +$ 41,700^c.

The result, therefore, based on the oxygen consumed should be regarded as the better one. The average of the results is 57,179^c at constant volume and 57,460^c at constant pressure for the heat effect of 16 grams of oxygen combining with cobalt to form chiefly crystalline cobaltous oxide. Dulong* made one determination of the heat of combustion of cobalt and found that 1 liter of oxygen combining with cobalt gave a heat effect of 5721^c. For 16 grams of oxygen the result is 64,000^c.

Cobaltous oxide in a finely divided and amorphous form oxidizes readily when heated in air to Co_3O_4, and Foote and Smith† have shown that the dissociation pressure of the latter oxide is 10^{mm} at 800°, the pressure rising rapidly with increasing temperature. These facts explain the formation of CoO when cobalt is burned in oxygen under pressure. The high temperature accompanying the reaction dissociates any Co_3O_4 formed into CoO and O and the molten CoO falling upon the cold bomb is quickly changed to a solid which as it cools takes up oxygen only on its surface. The following experiment shows the slow rate of oxidation: 1·1424 gram of finely pulverized cobaltous oxide of same lot taken for the analysis on p. 194 gained on heating to redness for 15 minutes in oxygen 0·0267, after 3 hours heating in air 0·0030, and then gained 0·0035 gram when heated an hour in oxygen. The total gain was 0·0332 gram; the calculated gain for complete oxidation to Co_3O_4 being 0·0812 gram.

2. *Heat of reaction of cobalt with sodium peroxide. Experiments 6 and 7.*—Cobalt 4·000, sulphur 1·000, sodium

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* C. R., xii, 871, 1838.
† J. Am. Chem. Soc., xxx, 1344.

peroxide 20 grams. Thermal effect for 1 gram of cobalt 1039^c and 1040^c. For 59 grams, $61{,}360^c$.

The fusions disintegrated slowly in cold water with evolution of oxygen. The insoluble black residue contained sodium, water and a peroxide.

3. *Heat of reaction of cobaltous-cobaltic oxide with sodium peroxide.*—Cobaltous-cobaltic oxide, prepared from carbonate by heating in air, yielded very nearly the theoretical amount of metal when reduced by hydrogen. It was in the form of a bulky powder.

Experiment 8.—Cobaltous-cobaltic oxide 6·000, sulphur 1·000, sodium peroxide 15 grams. Heat effect of 1 gram Co_3O_4 286^c.

Experiment 9.—Cobaltous-cobaltic oxide 9·000, sulphur 1·500, sodium peroxide 22 grams. Heat effect of 1 gram Co_3O_4 282^c.

The fusions were good and gave off much oxygen when placed in cold water. The black residue left by water retained alkali after prolonged digestion and washing with water. After remaining for several days in a vacuum over sulphuric acid it was found to yield water and oxygen when heated. The average of the two results is 284^c. For a gram molecule of Co_3O_4 it is $68{,}444^c$.

4. *Heat of reaction of cobaltous oxide with sodium peroxide.*—Amorphous cobaltous oxide was prepared by heating the carbonate in a current of dry carbon dioxide. The following are the experiments:

Experiment 10.—Cobaltous oxide 8·000, sulphur 1·000, sodium peroxide 18 grams. Heat effect of 1 gram cobaltous oxide 394^c.

Experiment 11.—Cobaltous oxide 10·266, sulphur 1·000, sodium peroxide 21 grams. Heat effect of 1 gram of cobaltous oxide 414^c.

The average of the two results, $404^c \times 75 = 30{,}390^c$.

Summary of Results on Cobalt.

$Co + O = CoO$ (crystalline) + ... $57{\cdot}5^c$
$Co + O = CoO$ (amorphous) + ... $50{\cdot}5^c$
$3Co + 4O = Co_3O_4 +$ .... $193{\cdot}4^c$

$3CoO$ (amor.) $+ O = Co_3O_4 +$ .... $41{\cdot}9^c$

$Co + 2Na_2O_2 = Na_2CoO_3 + Na_2O +$ .... $61{\cdot}4^c$
$2Na_2O + 2O = 2Na_2O_2 +$ .... $38{\cdot}8^c$

$Co + 2O + Na_2O = Na_2CoO_3 +$ .... $100{\cdot}2^c$

$Co_3O_4 + 2Na_2O_2 + Na_2O = 3Na_2CoO_3 +$ ...... $68{\cdot}4^c$
$2Na_2O + 2O = 2Na_2O_2 +$ .... $38{\cdot}8^c$

$Co_3O_4 + 2O + 3Na_2O = 3Na_2CoO_3 +$ .... $107{\cdot}2^c$

CoO (amor.) $+ Na_2O_2 = Na_2CoO_3 +$ .... $30{\cdot}3^c$
$Na_2O + O = Na_2O_2 +$ .... $19{\cdot}4^c$

$CoO + O + Na_2O = Na_2CoO_3 +$ .... $49{\cdot}7^c$

$Co + 2O + Na_2O = Na_2CoO_3 +$ .... $100{\cdot}2^c$
$CoO + O + Na_2O = Na_2CoO_3 +$ .... $49{\cdot}7^c$

$Co + O = CoO$ (amorphous) $+$ .... $50{\cdot}5^c$

$3(Co + 2O + Na_2O) = 3Na_2CoO_3 +$ .... $300{\cdot}6^c$
$Co_3O_4 + 2O + 3Na_2O = 3Na_2CoO_3 +$ .... $107{\cdot}2^c$

$3Co + 4O = Co_3O_4 +$ .... $193{\cdot}4^c$

Sodium cobaltite, Na_2CoO_3, has not been isolated, but very probably is formed in the fusions where there is an excess of sodium peroxide because cobaltites of other metals exist, as for example $BaCoO_3$, and $MgCoO_3$. Whether Na_2CoO_3 is formed in the fusion or some other sodium cobaltite makes no difference in the heat of oxidation derived, since the same cobaltite is formed in the fusions containing either cobalt or a cobalt oxide.

The heat effect of $Na_2O + CoO_2$ cannot be derived from the results, since the heat of formation of CoO_2 is not known. It is, however, $7{\cdot}8^c$ or greater. Assuming that one atom of oxygen combining with CoO gives the same heat effect as when combining with 3CoO, we have

$Co + 2O = 50{\cdot}5 + 41{\cdot}9 = 92{\cdot}4^c$
and $Co + 2O + Na_2O = Na_2O\ CoO_2 +$ .... $100{\cdot}2^c$
$Co + 2O = CoO_2 +$ .... $92{\cdot}4^c$?

$Na_2O = CoO = Na_2O\ CoO_2 +$ .... $7{\cdot}8^c$?

Nickel.

Two preparations of nickel were made from nickel carbonate from the J. T. Baker Chemical Company by converting it into oxide and then reducing with hydrogen. The preparation designated as *a* was reduced at a bright red heat. The nickel obtained was light gray and coherent. It was pulverized and sifted through 1/50 inch mesh. When burned in air it yielded only a trace of water, showing it to contain too little hydrogen to affect the calorimetric results. Another reduction was made (*b*) at a temperature of approximately 510°, and when it was complete the hydrogen was pumped out until the pressure fell to 30^{mm}. The apparatus containing the metal was then left to cool. When it was poured into a bottle oxidation took place so rapidly that the temperature of the metal rose 30°. The metal, marked *b*, was darker colored and more voluminous than *a*.

5. *Heat of combustion of nickel.*—The following are the experiments:

	1	2	3	4	
Nickel	12·000 (*a*)	18·003 (*b*)	22·099 (*b*)	16·000	grams (*a*)
Mica tray	0·576	0·677			
Silver tray			3·1245	3·188	"
Oxygen taken up	2·127	3·527	3·789	2·557	"
Water equivalent of system	3,568·	3,666·	3,647·	3,674·	"
Temperature interval	2·183°	3·470°	3·735°	2·508°	
Heat effect	7,789	12,721	13,622	$9,214^c$	
" of oxidation given	—48	—50	50	50^c	
	7,741	12,671	13,572	$9,164^c$	
For 1 gram of oxygen	$3,640^c$	$3,593^c$	$·3582^c$	$3,584^c$	

The average is 3600^c for 1 gram of oxygen combining with nickel. For 16 grams it is $57,600^c$ at constant volume and $57,900^c$ at constant pressure.

The product of a combustion was a sintered mass having the shape of the layer of metal burned. The trays holding the nickel were in all cases melted, the mica forming a slag adhering to the nickel oxide and the silver falling away from it. It was impossible to separate the metal from the oxide by a magnet as the two were so intimately mixed. In one trial an electromagnet removed 5/6 of the pulverized material from water. The product of experiment 4, in which a silver tray was used, contained a few black vitreous pieces which were also magnetic. Small globules of nickel were also present, showing that temperature of the combustion was high. The metal oxidized in experiment 1 was 65 per cent of the amount present; in 2, 75 per cent; in 3, 63 per cent; and 4, 59 per cent. The calculations are based on the oxygen taken up to form NiO, and there is no good reason for supposing that a lower oxide was formed.

The heat of oxidation of cobalt has been regarded as a little greater than that of nickel as indicated by Thomsen's results, which are $Co,O,H_2O = 63,400^c$, and $Ni,O,H_2O = 60,840^c$. Dulong's results* are of the same order, namely, $Co,O = 64,000^c$ and $Ni,O = 59,700^c$, each, however, from a single experiment found after his death recorded in his note-book.

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* Loc. cit.

The writer's results, on the contrary, are practically alike, thus: $Co+O=CoO$(crystalline)$+57,400^c$ and $Ni_2+O=Ni_2O+57,900^c$. As the nickelous oxide was sintered together and partly fused, it is compared with crystalline cobaltous oxide and not the amorphous form.

Nickel does not burn well enough with sodium peroxide to give a satisfactory result. The amorphous nickelous oxide is more finely divided than the metal and appears to burn better, but it is impossible to interpret a thermal result without other data.

Zinc.

6. *Heat of reaction of zinc with sodium peroxide.*—Zinc powder free from oxide was made by chipping off the metal on a lathe with a flexible chisel. A mixture of the powder and sodium peroxide burns when ignited by a hot wire with explosive violence and in a bomb yields a fused mass. Three combustions were made with the following mixtures:

	1	2	3	
Zinc taken	8·010	10·575	10·580	grams
" not oxidized	0·072	0·054	0·047	"
" oxidized	7·938	10·521	10·533	"
Sodium peroxide	10·	15·	15·	"
Heat effect of 1 gram of zinc	$1,021^c$	$1,048^c$	$1,033^c$	

The mean, $1033 \times 65·4 = 67,600^c$ from which the heat of formation of sodium zincate is derived, is as follows:

$$Zn + Na_2O_2 = Na_2ZnO_2 + \dots\dots\dots\dots \quad 67·6^c$$
$$Na_2O + O = Na_2O_2 + \dots\dots\dots\dots \quad 19·4^c$$
$$Zn + O + Na_2O = Na_2ZnO_2 + \dots\dots\dots\dots \quad 87·0^c$$

DeForcrand* prepared compounds which may be regarded as hydrated peroxides of zinc or zinc oxide and hydrogen peroxide, as for example $Zn_2O_5 + 2H_2O$ or $3ZnO + 2H_2O_2$. Hence the question—Was a peroxide formed in the fusions described? Evidently not, since in experiment 1 9·4 grams of sodium peroxide were required to form zinc oxide, and in 2 and 3, 12·6 grams.

DeForcrand† calculated the heat of formation of zinc oxide from the observations of other investigators, taking the atomic weight of zinc as 65, and obtained the following:

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* Ann. de Chem. et Phys. [7], xxvii, 26.

† Loc. cit.

Dulong	84·37^{c}
Andrews	87·20
Favre and Silbermann	84·04 82·88
Murignac	85·23
Ditte	88·16 87·73 85·46 83·22

The mean is 85·06^{c}. DeForcrand found for ZnO prepared at 125° 82·97^{c} and for oxide made at the temperature of burning zinc 84·7^{c}. Ditte also worked with preparations of zinc oxide which had been subjected to different temperatures. The results of the two investigators are essentially 83·0^{c} for zinc oxide prepared at a low temperature. Since the combustion of zinc with sodium peroxide gives only 87·0^{c} it is evident that the heat effect of $Na_2O + ZnO$ is very small, only 4·0 large calories.

Manganese.

7. *Heat of reaction of manganese with sodium peroxide.*—Manganese for the work was prepared by the Goldschmidt method. It was free from aluminum and contained a trace of silicon. Three combustions of the following mixtures were made:

	1	2	3	
Manganese	3·000	5·000	5·116	grams
Sulphur	1·000	1·000	0·500	"
Sodium peroxide	17·	30·	30·	"
Result for 1 gram of manganese	2237^{c}	2043^{c}	1985^{c}	

The fusions were green. Number 1 gave little gas when placed in water, the other two considerable gas. The solutions of all were green and much brown powder remained. In 1 the amount of sodium peroxide used was not sufficient to oxidize all of the manganese to MnO_3, and since the result is higher than the others the inference is that MnO_3 is formed from MnO_2 with absorption of heat.

The mean of the second and third results is 2014^{c} and for 55 grams of manganese it is 110,770^{c}. Hence, for the heat of the oxidation of manganese to MnO_3 plus the combination of the trioxide with sodium oxide we have

$$Mn + 3Na_2O_2 = Na_2MnO_4 + 2Na_2O = \ldots\ldots \quad 110{\cdot}8^{c}$$
$$3Na_2O + 3O = 3Na_2O_2 + \ldots\ldots \quad 58{\cdot}2^{c}$$

$$Mn + 3O + Na_2O = Na_2MnO_4 + \ldots\ldots \quad 169{\cdot}0^{c}$$

8. *Heat of reaction of manganese dioxide with sodium peroxide.*—Manganese dioxide was prepared by heating manganese nitrate until the residue ceased to lose weight at 400°. A weighed amount of the dioxide left on ignition very nearly the calculated quantity of Mn_3O_4.

Combustions of the following mixtures were made:

Manganese dioxide	8·000	10·000 grams
Sulphur	1·000	1·000 "
Sodium peroxide	19·	21· "
Result for 1 gram of MnO_2	368^c	323^c

The mean is 345^c and for a gram molecule of manganese dioxide it is 30·0^c, adding 19·4^c for the heat of Na_2O+O gives for $MnO_2+O+Na_2O=Na_2MnO_4+49{\cdot}4^c$.

For the heat effect of Mn + 2O we have $169{\cdot}0^c - 49{\cdot}4^c = 119{\cdot}6^c$. As the experiments do not show that Mn and MnO_2 are completely oxidized in the fusion to MnO_3 the results are to be regarded as approximations. The errors cannot be large since Le Chateliers* found that $Mn + 2O = MnO_2$ (crystalline) $+126{\cdot}0^c$ or 6·4^c more than given above for amorphous MnO_2; and the heat of formation of an amorphous compound is always less than that of the crystalline form. Manganese trioxide decomposes at common temperature into the dioxide and oxygen. This spontaneous change indicates that the reaction MnO_2+O is endothermic, at least it is not exothermic. The heat effect of $MnO_2,O, Na_2O = 49{\cdot}4^c$ results chiefly from the reaction Na_2O+MnO_3.

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* C. R., cxxii, 81.

ART. XX.—*Mosesite, a New Mercury Mineral from Terlingua, Texas;* by F. A. CANFIELD, W. F. HILLEBRAND, and W. T. SCHALLER.

Introduction.

THE name *mosesite* is proposed for a new mercury mineral from Terlingua, Brewster Co., Texas, in honor of Prof. Alfred J. Moses of Columbia University, New York, who first definitely described the interesting mercury minerals found in Texas. The three minerals, montroydite, terlinguaite and eglestonite, were named and definitely determined by him, and he also gave a preliminary notice of a fourth new one (later named kleinite). It is, therefore, with great pleasure on our part that we propose the name *mosesite,* which name, besides perpetuating the high attainments of Professor Moses in the science of mineralogy, is particularly appropriate as it links his name with a group of minerals which he first definitely put on record.

General Description (F. A. Canfield).

While examining a recently acquired specimen of montroydite and calcite the attention of the writer was attracted to some small yellow crystals which were perched upon the crystals of calcite. They did not join the montroydite but were isolated and solitary; they appeared to lie upon the surface of the calcite with but little or no bond. The slightest touch would loosen them, leaving no scar upon the calcite but merely a clean spot. A careful search revealed twenty-six crystals which will weigh, perhaps, ten milligrams. Twenty-two of the crystals are simple octahedrons, the others are spinel twins. No other forms were observed and none of the mineral was massive.

Another specimen has lately been procured which is much the finer in every way. Hundreds of crystals are scattered over a surface ($4^{cm} \times 6^{cm}$) of calcite which rests upon the pinkish rock which is characteristic of the Terlingua specimens. Nearly all of the crystals are spinel twins. They are frequently grouped together in confused masses; one polysynthetic twin—a 5-ling—was seen. Simple octahedrons are rare. None was modified by other forms. No other mercury mineral is present on the specimen unless some delicate, elongated, light yellow particles should prove to be kleinite.

It is impossible to tell to what conditions these specimens have been subjected. It is certain that the first specimen has been badly treated, since it is bruised and very dusty.

There are no indications that the crystals are affected by the light. If light affects the color it must act very slowly. The color of those crystals, which are so situated as to have some protection from the light, is exactly like that of the most exposed. No difference in color could be noted between the surface and the interior of the crystals. Most of the crystals are translucent. The largest crystal found is brilliant and transparent, and measures 0·5^{mm} along its edge. Generally the faces of the crystals are bright and uneven. They are very brittle with signs of cleavage.* The fracture is uneven. The hardness slightly exceeds that of calcite. The mineral crumbles to a powder under the pressure required for this test. No piece could be obtained that was large enough to determine the density. The luster is adamantine. The color is a rich lemon- to a canary-yellow. The streak and powder are a very pale yellow.

When heated gradually to a low temperature in a closed tube the assay turns to a dark reddish brown, almost black. As the heat increases the color changes rapidly to white, but without changing the form of the original crystals. Fumes of calomel are given off and condense in the tube. Many globules of mercury collect in the tube beyond the coating of calomel. Continued heating soon causes the assay to volatilize and disappear. If a fresh fragment of the mineral is heated rapidly in the closed tube, it decrepitates violently, almost explosively, then it fuses and volatilizes.

In cold hydrochloric acid the mineral is changed slowly to a white substance which retains the original form. If the acid is hot the change is more rapid but the product is the same.

It is to be hoped that enough of the material will be found to enable a complete analysis to be made. No doubt there are specimens of this mineral in some of the collections, but they are overlooked, or they are incorrectly labeled. The second of the above-described specimens was labeled "Terlinguaite." It is more like kleinite in appearance.

Chemistry (*W. F. Hillebrand*).

Chemically, so far as the very scanty material permitted of ascertaining, the composition of mosesite approaches that of kleinite, that is, it is a mercury-ammonium compound containing chlorine and the sulphate group besides a little water. Determinations made on 0·04 gram of material gave 5 per cent Cl and 3·5 per cent SO_4. The former amount is considerably lower and the latter somewhat higher than in kleinite, but the values are no more than approximations. There is, however, one marked chemical difference, which will be considered later.

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* Imperfect octahedral cleavage (W. T. S.).

Spectroscopic tests, that were kindly made by Dr. P. G. Nutting, at the Bureau of Standards, showed prominent mercury and nitrogen spectra and also the red line of hydrogen, the last being ascribed by him to water vapor. A singular feature of the behavior in vacuo was the immediate appearance, when the current was turned on and before the application of heat, of a mercury spectrum. The mineral was at the time not between the electrodes, but far to the rear of one of them, at the sealed end of the Plucker tube. Under these conditions the color of the mineral fragments underwent a pronounced and permanent change from bright yellow to a yellowish gray. With a minute crystal of kleinite there was a mere indication of the mercury lines before heating, and no color change was observed. As soon as the temperature of mosesite was raised to visible incipient decomposition, the spectra of both nitrogen and mercury became brilliant. As mentioned by Mr. Canfield, mosesite does not seem to undergo the color changes in sunlight and darkness that appear to be characteristic of the deeper colored crystals of kleinite.

When heated in a narrow tube closed at one end, the color changes and the sublimates were much like those afforded by kleinite, and there was the same liberation of an active gas that set free iodine from potassium iodide. Ammonium bromide liberated ammonia as from kleinite.

The behavior towards hydrochloric acid, noticed by Mr. Canfield, affords a certain chemical means of distinguishing mosesite from kleinite, where only these two are concerned. When covered with concentrated hydrochloric acid mosesite is entirely decomposed in a few hours, with separation of a coherent white material that shows the behavior of calomel. The solution contains the sulphate and ammonium groups, beside much mercuric mercury. Kleinite, on the other hand, shows no perceptible change for a long time, but in the course of 48 hours a minute crystal of it was almost entirely decomposed. There remained only a whitish residue that looked as if it might be the clay matter that is such a persistent contaminant of the mineral. It was free from calomel.

It will be remembered that the chemical evidence points to kleinite being a mixture or solution of mercury-ammonium chloride with a mercuric sulphate and perhaps chloride. There would seem to be an association of similar general character in mosesite, but with a mercurous sulphate or chloride replacing in part or wholly the corresponding mercuric salts of kleinite.

Crystallography and Optical Properties (*W. T. Schaller*).

The crystals are apparently octahedra of the isometric system. Twinning on the spinel law has been observed several times, in which case the crystals of mosesite are often flattened parallel to a pair of octahedral faces. Mr. Canfield has mentioned a 5-ling, a spinel twin repeated five times.

The faces of the crystals are never smooth. While bright and often highly polished, they are uneven and only a few of the faces give a single reflection. Most of the faces when measured on the goniometer give a number of signals, no particular one of which is brighter than the others. This has rendered the accurate determination of the form of the crystals impossible. An additional feature that has rendered accurate measurements difficult is the tendency for a number of crystals to grow together, sometimes in nearly parallel position and again in widely different positions. A mass of signals therefore resulted from examining such groups of mosesite on the goniometer, and on the minute crystals that were available it was not possible to know what signals to measure and what ones to exclude. Where only two or three faces were measured in a zone, it was well nigh impossible to be sure of having the zone accurately centered. The measurements, the occurrence of (probable) spinel twins and the optical relations, to be described below, make it fairly certain that the crystals of mosesite are in reality octahedra. No form other than the octahedron was observed.

On part of a spinel twin, the faces of which gave a mass of very poor reflections, there were measured:

$o \wedge o'$	= 68°	70° 32′ calc.
	= 68° (cleavage face)	" "
	= 68° 28′	" "
$o \wedge \underline{o}$	= 41° 13′	38° 56′ "

A second crystal, also a spinel twin, gave:

$o \wedge o'$	= 108° 54′	109° 28′ calc.
	= 107° 53′	" "
	= 71° 38′	70° 32′ "
	= 70° 47′	" "
	= 68° 51′	" "
	= 72° 28′	" "
$o \wedge \underline{o}$	= 37° 06′	38° 56′ "
	= 38° 56′	" "

A third crystal was adjusted as closely as possible in polar position for two-circle measurement and on revolving the crystal, the four octahedra faces were seen to lie in the positions required for the form (111).

From the above data, meager and poor as they are, the isometric character of the crystals is deduced, especially as this is supported by the investigation of the optical properties.

Under the microscope mosesite is pale yellow, non-pleochroic and seems to possess a rather low double refraction. When a fragment is crushed many of the resultant pieces show the octahedral cleavage, either in their triangular or rhombic shape (when only two directions of cleavage are developed) or in three series of cleavage lines, parallel to the octahedral faces. A fragment of fluorite was crushed and examined under the microscope, when similar effects were seen, though in this case the cleavage was much better developed.

The crystallographic investigation has shown that the crystals are in all probability isometric octahedra and should, therefore, be isotropic when examined under the microscope with crossed nicols. Such an examination, however, shows the mineral not to be isotropic but doubly refracting. On heating the mineral to 186°, the crystals lose their double refraction and become isotropic. Mosesite is therefore dimorphic, the isometric optical condition that agrees with the geometrical form being stable only above 186°, the mineral changing to the dimorphous doubly refracting condition at temperatures below 186°.

As examined at ordinary temperatures, i. e., as the mineral now occurs, the sections show great similarity to kleinite. Much of the material does not extinguish at all, other parts do so four times during a complete revolution of the stage and the interference-colors are fairly brilliant. On crushing a fragment between two glass slides and examining the very minute particles, they are seen to be nearly colorless and, unlike the larger pieces, isotropic. It seems as if the local heat developed by the crushing is sufficient to heat these small particles to at least 186° and cause their reversion to the isotropic state.

Several different fragments were heated on glass slides, in an air oven to the temperature given, with the results shown in the following table:

Effect of heating Mosesite.

Slide with mosesite.	Temp.	Effect.	Probable temp. of change.
First	150°	No change, mineral still doubly refracting.	
	200°	Brown and isotropic.	150–200°
Second	160°	Brown and doubly refracting.	
	167°	Still doubly refracting.	
	180°	" " "	
	189°	Isotropic.	180–189°

Third	169°	Doubly refracting, but section too opaque for further study.	Above 169°
Fourth...	169°	Doubly refracting.	
	184°	" "	
	186°	Nearly isotropic.	
	190°	Isotropic.	186–190°
Fifth	184°	Doubly refracting.	
	186°	Nearly isotropic.	
	188°	" "	
	190°	Isotropic, except for a few minute doubly refracting spots.	184–186°
Sixth	186°	Doubly refracting.	
	192°	Still doubly refracting in places but partly isotropic. This particular piece may have been thicker than the others and therefore did not revert so readily.	186–192°+
Seventh ..	186°	Isotropic on thin edges, but doubly refracting in thicker center.	
	192°	Isotropic.	186–192°

From these data the temperature of reversion to the isotropic isometric state probably lies between 180° and 190° and is taken as 186°. If the "molecular inertia" of mosesite is considerable, as is the case with kleinite,* then this temperature, namely 186°, is probably a little high. On cooling, the isotropic mineral does not immediately again become doubly refracting. Examination after 24 hours shows the mineral to be still isotropic. The change back seems to be, like that of kleinite, a very slow one, but doubtless it is gradually taking place. The section of kleinite described † as almost entirely reverted after thirty months is now, after four years, completely changed back again to its original doubly refracting condition.

The optical similarities, shown by these two minerals, coupled with their evident chemical relationship, suggested trying the effect of heating kleinite to the reversion temperature of mosesite (186°). When this was done, kleinite ‡ became optically isotropic like mosesite. The results of the experiments are shown in the table below.

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* Hillebrand, W. F., and Schaller, W. T., The Mercury Minerals from Terlingua, Texas. Bull. U. S. Geol. Survey, No. 405, 1909, p. 26.

† Loc. cit., p. 25.

‡ Fragments were used that were not parallel to the base as these would become isotropic at 130°, kleinite being uniaxial, hexagonal.

Effect of heating Kleinite.

Slide with kleinite.	Temp.	Effect.
First	177°	Doubly refracting, no change.
	187°	“ “ “ “
	194°	“ “ “ “ Probably too thick.
Second	177°	Doubly refracting, no change.
	194°	Isotropic.
Third	177°	Doubly refracting, no change.
	194°	Partly isotropic, the remainder doubly refracting as before. The isotropic part while still transparent had become brown, the doubly refracting part remaining pale yellow.

It would be premature to speculate on the significance of this observation on the optical behavior of kleinite.

ART. XXI.—*Researches upon the Complexity of Tellurium;*

by WILLIAM R. FLINT.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxiv.]

Introductory.

IN two papers* from this laboratory a description has been given of a hydrolytic method for the fractionation of tellurium. An account also has been given, in the second paper, of results obtained from a preliminary application of the process in which it was indicated not only that the substance might really be complex in spite of the almost conclusively negative evidence hitherto adduced, but also that its anomalous position in the periodic system might be due to the actual presence, as Mendeléeff predicted, of a constituent having a higher atomic weight.

In the work referred to, the fractionation was so conducted as to produce both end fractions simultaneously, and since the method employed was practically that of fractional crystallization, this involved, unless the operation had been long enough continued, the introduction into each of these portions of material from the middle fractions.

It was therefore determined to modify the fractioning process in such a way as to secure a more rapid separation of each end fraction independently, and to apply it to a much larger amount of material.

Preparation of Material.

About one kilogram of crude tellurium dioxide, extracted by hydrochloric acid from electrolytic copper residues, supplied by the Baltimore Copper Smelting and Rolling Co., was treated by the same purification processes as those described in the papers cited, the distillation and redistillation, in hydrogen, being performed in this case in a silica tube, from porcelain boats. The tube was very carefully cleaned between the distillations, and, in redistilling, fresh boats were used.

Plan of the Investigation.

From the method of fractioning adopted, the investigation naturally divides into two parts, in the first of which will be described (1) determinations of the atomic weight of the tellurium in unfractionated material; and (2) the preparation by hydrolysis with water of a series of fractions, together with atomic weight estimations made upon the tellurium in them. In the second part will be given an account of an experiment upon a fractionation by nitric acid, and of a preliminary investigation of the less easily hydrolyzed fraction.

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* **Browning and Flint, this Journal, xxviii, 112 and 347.**

PART I.

As a check upon the whole work, one hundred and fifty grams of the purified product were dissolved in nitric acid (sp. gr. 1·25) and crystallized out as basic nitrate by evaporation of the solution at about 85° C. After being washed with concentrated nitric acid, the basic nitrate was dried by heating at 110° to 120° C. in specially constructed electric drying ovens through which was passed a current of air dried by sulphuric acid. The air was bubbled first through a solution of potassium hydroxide, then through concentrated sulphuric acid, and finally filtered by passing through a tower containing cotton wool.

Portions of this preparation were then weighed out in platinum and brought to constant weight by heating, for periods of about twelve hours each, at 140° C. in air dried as just stated, in the electric heaters. The temperature was next raised, and the nitric acid expelled from the compound by ignition up to 425° to 450° for twenty to twenty-four hours. The experiments were finally completed by a short ignition over a bunsen burner at such a temperature as would ensure a glassy condition of the fused dioxide.

In all the basic nitrate experiments detailed in this paper, the weighings were made by the method of oscillations, a standardized set of weights employed, and a correction for the inequality of the balance arms applied. Lastly, the weights were reduced to a vacuum. The corrected results of the determinations made upon the unfractionated material, which, excepting number 5, were performed in pairs, are given in Table I. It should be added that in no case was there evidence of the escape of traces of dioxide by volatilization.

TABLE I.

Unfractionated Material.

Exp.	$2TeO_2.HNO_3$ taken grms.	$2TeO_2$ found grms.	Atomic weight of tellurium
1	4·26930	3·56471	127·41
2	3·66863	3·06339	127·48
3	3·17350	2·64983	127·46
4	3·43498	2·86827	127·48
5	5·47269	4·56963	127·44
	20·01910	16·71583	127·45 (**Mean**)

It may be noted that the mean atomic weight, 127·45, is practically identical with that found by Norris,[*] and that the concordance of these experiments is quite as good as those given by him. The close agreement of this result with both the figure given by Norris and also those found by numerous other investigators indicates a complete correspondence in quality between the material employed in the present research and that used by others. It also confirms the general conclusion that the atomic weight of tellurium, when prepared by the ordinary methods, is 127·5.

The Fractionation by Water Hydrolysis, and Atomic Weights of the Fractions Obtained.

(See accompanying plan.)

Five hundred grams more of the redistilled tellurium were oxidized by nitric acid and converted to tetrachloride by repeated evaporation with hydrochloric acid. The solution, containing as little excess of acid as possible, was, in four portions, diluted with about four liters each of boiling distilled water and allowed to cool. The white, crystalline dioxide which separated out was collected on a filter and washed. After solution in hydrochloric acid (in slight excess) it was reprecipitated by abundant dilution as before. When the fourth repetition of this process had been made, using in each case only the dioxide which had been previously precipitated by dilution, a small portion of the fourth precipitate was taken out as a sample. This was crystallized from nitric acid by the usual method, and a second series of basic nitrate experiments, conducted in every way like those of Table I, was performed. The data of these are found in Table II.

Table II.

After Four Fractionations.

Exp.	$2TeO_2.HNO_3$ taken grms.	$2TeO_2$ found grms.	Atomic weight of tellurium
1	3·07931	2·56876	126·53
2	2·73622	2·28276	126·62
3	2·36328	1·97153	126·57
4	2·08497	1·73948	126·64
	10·26378	9·56253	126·59 (Mean)

The fractionation process was continued with the remainder of the fourth precipitate in the same manner as before, and the operations repeated without change until ten fractionations

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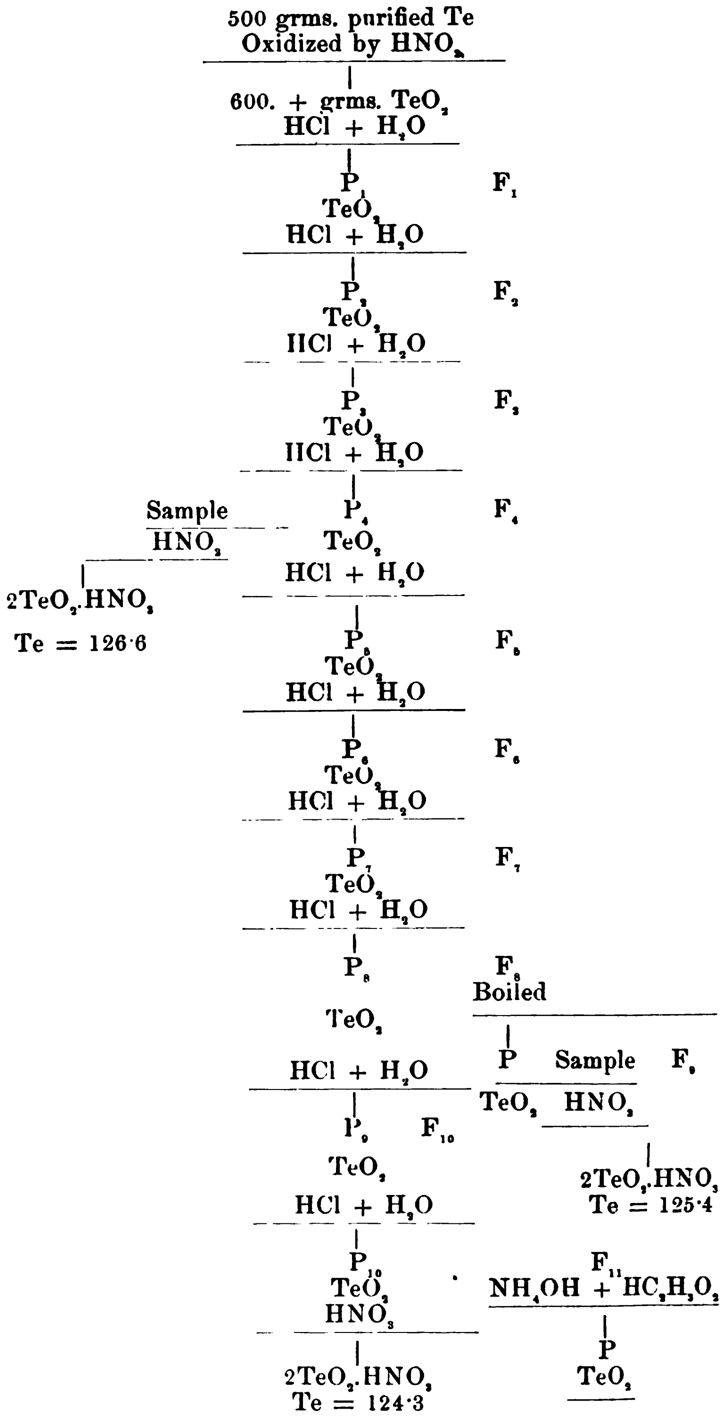
[*] J. Am. Chem. Soc., xxviii, 1675.

Plan of the First Fractionation.



had been performed. By heating to boiling the filtrate from the eighth precipitate a further separation of dioxide was obtained from this liquid, and boiling for ten or fifteen minutes threw out about 42 grams. Part of this sample was converted to basic nitrate and subjected to the same process of analysis as the previous preparations, the results being recorded in Table III.

TABLE III.

After Eight Fractionations.

(From filtrate.)

Exp.	$2TeO_2.HNO_3$ taken grms.	$2TeO_2$ found grms.	Atomic weight of tellurium
1	2·12253	1·76842	125·36
2	2·51320	2·09413	125·45
3	3·76225	3·13447	125·32
4	3·88080	3·23336	125·36
	12·27878	10·23038	125·37 (Mean)

Fraction ten consisted of but twenty-three grams of dioxide. Since the fractioning process had reduced the quantity of dioxide from over 600 grams to a little more than twenty, it seemed possible that the limit might have been reached. About fifteen grams were consequently transformed to basic nitrate, in two separate preparations. The purpose of this was to eliminate, if possible, the objection that this lowering of the atomic weight might be due to lack of constancy of composition of the basic nitrate. The first sample, the data of whose analysis by the basic nitrate method (applied exactly as described for the preceding preparations) are given in experiments one and two of Table IV, contained about five grams; the second, experiments three to seven, sixteen grams.

TABLE IV.

After Ten Fractionations.

Exp.	$2TeO_2.HNO_3$ taken grms.	$2TeO_2$ found grms.	Atomic weight of tellurium
1	2·06311	1·71688	124·25
2	2·18903	1·82172	124·27
3	3·56161	2·96446	124·42
4	2·99821	2·49537	124·37
5	2·86977	2·38824	124·27
6	2·47403	2·05898	124·31
7	4·85363	4·03943	124·32
	21·00939	17·48508	124·32 (Mean)

The concordance of these results is sufficiently close to indicate that the two preparations of fraction ten were practically constant in composition. Experiment 7 in the above table was performed in parallel with experiment 5 of Table I.

A comparison of the mean values given in the four preceding tables shows a remarkable lowering of the atomic weight with the progress of the fractionation. In considering the difference between the mean result, 124·3, of Table IV, and that, 125·4, of Table III, it should be noted that, since the material which gave the latter figure was derived from the filtrate of fraction eight, it was to have been expected that its atomic weight would be higher than that of fraction eight itself. Owing to the small quantity remaining of fraction ten, it was impossible to make another direct fractionation. But the dioxide produced in the experiments of Table IV was dissolved in hydrochloric acid and the hydrolysis repeated once more, the precipitate being converted to basic nitrate. The basic nitrate experiments gave 124·62 and 124.64, but these figures cannot be accepted as conclusive. In the first place, they were made upon material which had already been used for previous determinations, in which the dioxide formed had been heated in platinum up to fusion. During the course of the basic nitrate experiments described in this paper, a progressive, but minute, loss of weight was observed in the platinum crucibles used. This fact suggests the possibility that the tellurium may have become contaminated with a little platinum, which would of course raise the atomic weight found in these two experiments. And second, while these two experiments were in progress, an extreme humidity unfortunately characterized the weather. The tendency of this condition would be to increase the atomic weight also, since traces of moisture absorbed by the basic nitrate during those short, but necessary, periods in which it was out of the heaters and desiccator for the purpose of weighing, would tend to produce hydrolysis to dioxide, and the nitric acid liberated from the compound would be expelled in the next heating. This also would increase the value found for the atomic weight. It is therefore at present impossible to conclude with certainty that the figure 124·3 represents the true atomic weight of the element tellurium, since the value may perhaps lie a little below this number.

Conclusion.

Using the customary methods of purification, a large quantity of tellurium has been prepared. By the basic nitrate process, this has been shown, in five experiments with 20 grams of material, to have the atomic weight 127·5, generally accepted for tellurium. Repeated hydrolysis with hot water of a solution of 500 grams of this preparation in hydrochloric acid has furnished, in ten fractionations, a product consisting of twenty-three grams of dioxide. The tellurium in this fraction, it has been demonstrated, also by the basic nitrate method in seven experiments using twenty-one grams, has an atomic weight of 124·3. Two intermediate fractions, estimated in the same way, give values of 126·6 and 125·4 respectively, these three results taken together exhibiting a progressive diminution of the atomic weight.

In March of the year 1869, Mendeléeff, in announcing the periodic law, made the following statement:[*] "Die Atomgewichtsgrösse eines Elementes kann bisweilen corrigirt werden, sobald seine Analogien bekannt sind. So muss dass Atomgewicht des Te nicht 128, sondern 123–126 sein." The problem inferentially stated by him, which for the last forty years has supplied the subject matter of researches too numerous to mention, appears to have been solved, and affirmatively, by the research herein described.

Brauner's[†] various low results which he published in 1889; Heberlein's[‡] value of 126·99; Steiner's,[§] of 126·4, obtained in 1901 by fractional distillation of diphenyl telluride; Marckwald's,[‖] of 126·85 in 1907, from fractional crystallization of telluric acid; and the figure 126·53, found in 1909 by Browning and Flint,[¶] using hydrolysis with water, have been the chief divergences in the past from the accepted value.

The present investigation has furnished more than twenty grams of a purified product possessing an atomic weight of 124·3. Since this preparation was extracted from a large quantity of material which is proved by its atomic weight, 127·45, to correspond to what has been hitherto considered elementary substance, the figure 124·3 is apparently the nearest approach which has yet been made to the true atomic weight of the element tellurium.

PART II.

(Preliminary.)

Experiments upon a Fractionation by Nitric Acid.

In the purification of some crude tellurium by three crystallizations from nitric acid, by the method of Norris, Fay, and Edgerly,[**] it was observed that a part was rather more insoluble than the rest, in the nitric acid used (sp. gr. 1·25). A separation was effected by decantation of the liquid from the less soluble portion. Both fractions were then evaporated to dryness and ignited to dioxide. Carefully weighed equal quantities of these samples were dissolved with equal amounts of hydrochloric acid and diluted with equal amounts of boiling water. After standing for some hours, the precipitates were collected upon Gooch crucibles and washed, dried, and weighed. It was found that the fraction more insoluble in nitric acid gave about 6·5 per cent more dioxide, by the hydrolysis from hot water, than the other, or more soluble, portion. It was proved that this difference was not due to the presence of impurities detectable by careful qualitative analysis.

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[*] C. f. Ber., xiii, 1799.

[†] J. Chem. Soc., lv, 382.

[‡] Dissert. Basel, 1898.

[§] Ber., xxxiv, 570.

[‖] Ber., xl, 4730.

[¶] Loc. cit.

[**] Am. Chem. Jour., xxiii, 105.

A similar difference in solubility (in nitric acid) was noted in a recrystallization of part of the basic nitrate prepared from the 150-gram portion of purified tellurium described in Part I of this paper. After the whole of the sample taken had been finally gotten into solution, the greater part was thrown out, as basic nitrate, by sufficient concentration, and the liquid from which it had separated decanted from the crystals. These crystals were washed, and dried in the heater, as usual. The mother liquor was then evaporated to dryness and the residue ignited almost to redness, whereupon it developed an orange-red color and became distinctly crystalline in texture. The color was proved not to be due either to iron or to selenium, by the ordinary tests.

Basic nitrate experiments performed upon the less soluble fraction, exactly as described in Part I, furnished the data (corrected) of the accompanying Table V.

TABLE V.

Exp.	$2TeO_2.HNO_3$ taken gms.	$2TeO_2$ found gms.	Atomic weight of tellurium gms.
1	1·98132	1·65281	126·53
2	1·34204	1·11947	126·48
3	1·36589	1·13945	126·55
4	1·17057	0·97655	126·59
5	1·07610	0·89765	126·50
6	0·98468	0·82145	126·57
7	1·67119	1·39396	126·44
8	1·53443	1·28006	126·56
9	2·53215	2·11231	126·53
10	2·46437	2·05543	126·37
	16·12274	13·44914	126·51 (Mean)

The mean value found in this table, 126·5, is identical with that given by Browning and Flint as referred to in Part I. It is likewise practically identical with the mean, 126·58, of Table II, in the previous part. Whether this fact indicates that a more rapid fractionation can be secured by the hydrolysis of the nitrate than by that of the chloride, remains for further investigation to prove.

Atomic weight determinations of the more soluble fraction have not as yet been made.

Investigation of the Fraction less easily Hydrolyzed by Water.

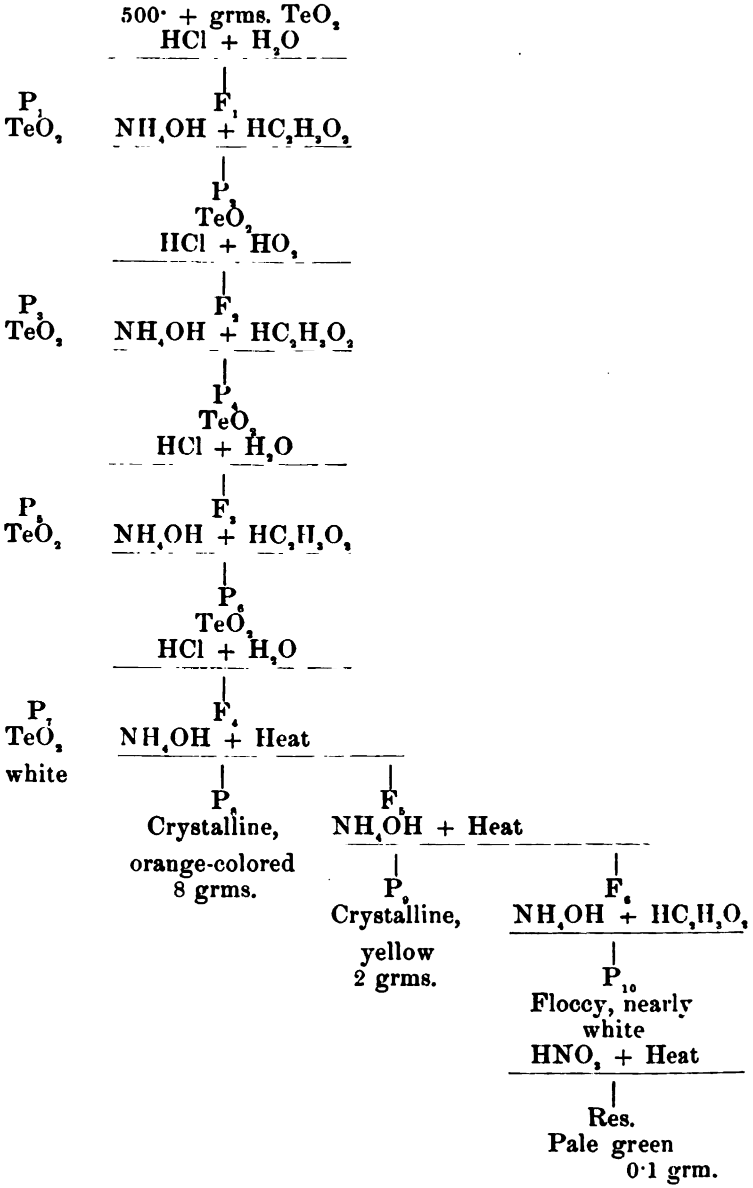
(See accompanying plan.)

The tellurium in the filtrates from the water hydrolysis described in the preceding part was recovered by treatment with ammonia and acetic acid. The dioxide thus secured was next dissolved in hydrochloric acid and the solution was diluted abundantly with boiling water and allowed to cool. The filtrate from the dioxide thus precipitated was again heated to boiling, and ammonia and acetic acid were added, in the usual way, to complete precipitation as dioxide of the remaining tellurium. This latter portion was re-treated in the same manner, and the process repeated twice more, each time using only the ammonia-acetic acid precipitate from the preceding operation.

As the result of these four fractionations, almost exactly 500 grams of dioxide were obtained by the water precipitation, while the unhydrolyzed fraction secured by ammonia and acetic acid consisted of scarcely more than ten grams. From the fifth repetition, on the ten gram portion, a very small quantity of crystalline, pure white dioxide was obtained by dilution and cooling of the hydrochloric acid solution. The filtrate was heated to boiling and sufficient ammonia added to neutralize part of the acid, whereupon an orange-colored, crystalline deposit, similar to that obtained in the nitric acid fractionation above described, began to form. Boiling for ten or fifteen minutes threw out about eight grams of this product, which was separated by decantation of the liquid, washed, and dried.

After filtering the liquid and reheating it to boiling, more ammonia was added, but still not enough to neutralize all the acid present. By this means another crystalline deposit was secured, yellow in color, and only a gram or so in quantity. When the filtrate from the last mentioned substance was again heated and finally precipitated completely by ammonia and acetic acid, a minute amount of floccy precipitate appeared. Nothing precipitable by stannous chloride in either acid or alkaline solution was found in the last filtrate, and it was therefore rejected. The floccy precipitate was collected on a filter, washed, and dried. Its amount was too small to admit of its

Plan of the Second Fractionation.



being removed from the paper in any other way, and it was consequently dissolved off by nitric acid (sp. gr. 1·25), the solution filtered twice on asbestos, and evaporated to dryness. The final product, which was ignited nearly to redness, consisted of about one-tenth of a gram of a pale green powder.

The color of two of these substances suggested possible contamination by iron; that of the third by copper, or perhaps tungsten. No slightest traces of either iron or copper can be discovered by the usual tests. In hydrochloric acid solution all three give, with stannous chloride, black precipitates, similar to tellurium. No bismuth or antimony can be detected. In fact, all reactions so far tried appear to be identical with those given by tellurium, with one exception. When an excess of ammonia is added to a solution of the green substance in hydrochloric acid, the precipitate obtained by neutralization of the acid is not completely dissolved by the excess of the alkali. The liquid filtered from this throws out a black substance, apparently tellurium, when acidified and treated with stannous chloride. The precipitate which did not dissolve in the excess of ammonia, when dissolved, after thorough washing, in hydrochloric acid, gives also a black precipitate with the same reagent. Since tungstic oxide is soluble in ammonia, but is not precipitated (although reduced to lower oxides) by stannous chloride, the presence of tungsten is apparently disproved. It is besides difficult to understand how an element having a fusing point above 3000° C. could be volatilized with the tellurium in the process of distillation at a very much lower temperature than this.

By the use of a greater quantity of material, the investigator proposes to extract sufficient amounts of these products to enable him to determine their nature. This work is already begun, and a report upon it will be made as soon as it can be completed.

ART. XXII.—*The Gravimetric Estimation of Vanadium as Silver Vanadate;* by PHILIP E. BROWNING and HOWARD E. PALMER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxv.]

SILVER nitrate has long been known as a precipitant of solutions of vanadic acid, but, so far as the authors are aware, no method for the quantitative estimation of vanadium, based on the use of this reagent, has been published. The work to be described was undertaken to determine the conditions under which vanadium could be estimated gravimetrically as silver vanadate.

For this work an exactly neutral solution of ammonium vanadate was used, whose standard had been determined by evaporating accurately measured portions to dryness in a platinum crucible and weighing as V_2O_5 after gentle ignition.

Attempts were first made to precipitate the silver vanadate in acetic acid solution. The solution of ammonium vanadate, acid with acetic acid, was heated to boiling, and a solution of silver nitrate was added, with stirring to coagulate the precipitate. The precipitate, after settling, was filtered off on asbestos, washed thoroughly, and weighed after gentle ignition. The experiments made in this way, under different conditions of acidity, and with different amounts of silver nitrate, are recorded in Table I, and indicate a variation in the composition of the precipitate which is formed in acetic acid solution.

TABLE I.

	V_2O_5 taken grm.	Silver vanadate found grm.	V_2O_5 found grm.	Error grm.
(1)	0·0569	0·1978	0·0871	+0·0302
(2)	0·0569	0·1202	0·0529	—0·0040
(3)	0·1139	0·2275	0·1002	—0·0137
(4)	0·0569	0·2671	0·1176	+0·0607
(5)	0·0569	0·1717	0·0756	+0·0187

The effect was next tried of making the precipitation in exactly neutral solution as follows: The neutral solution of ammonium vanadate, about 200^{cm^3} in volume, was heated to boiling, and a solution of silver nitrate was added in excess, with vigorous stirring to coagulate the precipitate. The precipitate was then filtered off on an asbestos felt contained in a platinum crucible, washed thoroughly, ignited at a gentle heat below the fusing point of silver vanadate, and weighed as $AgVO_3$.

The results, recorded in Series A of Table II, indicate that the composition of the precipitate formed in neutral solution approximates closely to the meta-form.

In the experiments recorded in Series B of Table II, the solution of ammonium vanadate was made ammoniacal with ammonium hydroxide, and this solution was made neutral by boiling until the ammonia was completely expelled. To this solution, diluted to about 200^{cm^3}, and heated to boiling, silver nitrate was added, and the procedure given above was followed. The results indicate that the precipitate formed by adding silver nitrate to a solution made neutral by boiling off the ammonia from an ammoniacal solution, is of constant composition.

The experiments of Series C were made to determine whether any solution containing vanadium could be brought into the condition in which the silver metavanadate would be precipitated on the addition of silver nitrate, by making ammoniacal and boiling off the ammonia. To this end the solution of ammonium vanadate was made acid with nitric acid, then made ammoniacal with ammonium hydroxide, and boiled to expel the ammonia; the solution was then treated as in the experiments of Series A. This method, as will be seen, gave the most satisfactory results. In this connection it should be noted that the ammoniacal solution, which is yellow at first, becomes colorless during the boiling, until finally, when the ammonia is almost completely expelled, the solution begins to turn yellow; the boiling should be stopped as soon as the solution begins to turn faintly yellow, because, if the boiling is continued further, the solution becomes too acid, and the precipitate which forms on the addition of silver nitrate has a varying composition which does not correspond to the meta-condition.

The ease with which the silver vanadate settled out on stirring suggested that the vanadium might be estimated volumetrically with a fair degree of accuracy, by adding a standard solution of silver nitrate to the hot neutral solution containing the vanadium, and noting the point at which the precipitation ceased: but attempts to do this met with unsatisfactory results.

The gravimetric estimation of silver by the addition of an excess of a solution of ammonium vanadate to the solution containing the silver was also tried, but was abandoned on account of the unsatisfactory character of the precipitate and the difficulty with which it filtered.

TABLE II.

	V_2O_5 taken grm.	$AgVO_3$ found grm.	V_2O_5 found grm.	Error grm.
		(A)		
(1)	0·1139	0·2595	0·1143	+0·0004
(2)	0·0569	0·1291	0·0569	+0·0000
(3)	0·0569	0·1277	0·0562	+0·0007
(4)	0·0569	0·1303	0·0574	+0·0005
(5)	0·1066	0·2436	0·1073	+0·0007
		(B)		
(1)	0·1066	0·2430	0·1070	+0·0004
(2)	0·1066	0·2429	0·1070	+0·0004
(3)	0·0533	0·1224	0·0539	+0·0006
(4)	0·0533	0·1221	0·0538	+0·0005
(5)	0·0569	0·1312	0·0578	+0·0009
		(C)		
(1)	0·0569	0·1293	0·0569	—0·0000
(2)	0·1066	0·2419	0·1065	—0·0001
(3)	0·1066	0·2424	0·1068	+0·0002
(4)	0·1066	0·2422	0·1066	+0·0000
(5)	0·0533	0·1215	0·0535	+0·0002

ART. XXIII.—*On the Brachiopod genus Syringothyris in the Devonian of Missouri;* by CHARLES SCHUCHERT.

(Contributions from Peabody Museum, Yale University, New Haven, Conn.)

AMERICAN species of *Syringothyris* are said to be restricted to the Lower Carboniferous or, better, the Mississippian, and are known to range from the base of this system into the Spergen formation (Lanesville, Indiana). Professor Greger, of Fulton, Missouri, recently sent the writer specimens of *Cyrtia occidentalis* Swallow (Trans. St. Louis Acad., i, 1860: 648) that are unmistakable individuals of *Syringothyris*. These he gathered from the type locality of the species in the Callaway limestone at Bellamy Springs and elsewhere in Callaway County, Missouri. This limestone is here the basal member of the Devonian invasion, and appears to be either of late Middle or early Upper Devonian time.

The syrinx in *S. occidentalis* is as well developed as in *S. hannibalensis*, in both of which this plate, for pedicle muscle attachment, has not yet developed into the typical form described as the split tube by Hall and Clarke (Pal. N. Y., viii, pt. ii, 1894: 48). In these species the under side of the syrinx is slightly concave, widely open along the inner free end, and is marked by converging muscular growth ridges medially divided by a faint septum. In *S. hannibalensis* the lateral walls of the syrinx close inward and form a more or less well-developed split tube. In other and later species the tube is solid and only the innermost free end has a short depression to which the pedicle muscles are attached.

S. occidentalis is as a rule less transverse than the other species of *Syringothyris*, and in this is most like the earliest Mississippian species. In the later forms *S. carteri* and *S. texta* the valves are more transverse.

Keyes was the first to refer Swallow's species to *Syringothyris* (Missouri Geol. Surv., v, 1894: 86), but as he gave no reasons for this reference and as the writer (Bull. U. S. Geol. Surv., 87, 1897: 199) had not then seen this shell, he preferred to follow Miller's North American Geology and Paleontology, where it is placed doubtfully under *Cyrtina*.

Syringothyris therefore originated in the Cordilleran sea during the later Devonian and not in the Atlantic province as the writer heretofore held, but it was not a conspicuous member of any fauna until Mississippian time. The genus is then present in most of the formations from the early Kinderhook to the Keokuk, and it persists even into the Spergen of the Meramecian series. At no time, however, was there more than one species in a fauna and all these are very much alike.

Another phylum originated in the Atlantic realm of the Appalachian province in *Spirifer randalli*, which also has a well-developed syrinx, but differs from *Syringothyris* of the Mississippian sea in having a strongly plicated fold and sinus. This stock must be separated generically from those of the Mississippian sea because of its different phyletic derivation, and for it is proposed the generic name *Syringopleura* (from *syrinx* and *pleura* or rib, having reference to the plicated fold and sinus), with *S. randalli* Simpson as the genotype. Another species probably also belonging to this stock is *Spirifer alta* Hall. Both occur in the basal Mississippic strata of the Appalachian province and appear to have no later descendants.

Another similar development took place during the Upper Devonian (Ouray limestone) in the southwestern Cordilleran sea in *Syringospira prima* (Kindle, Bull. U. S. Geol. Surv., 391, 1909 : 28), a form with an excessively drawn out ventral cardinal area, and valves finely plicate throughout.

Hall and Clarke mention still other stocks of *Spirifer* that tend to develop a syrinx. It would therefore appear that any late Devonian or late Mississippian *Spirifer* with a high cardinal area accompanied by much testaceous deposit in the rostral cavity of the ventral valve between the dental plates, may develop a more or less typical syrinx.

The pedicle in all these forms emerges near the articulating cardinal edge in front of the syrinx and between the slightly diverging deltidial plates. To avoid the lengthening of the inner attached end of the ventral pedicle muscle there was developed the syrinx, a delthyrial plate that was progressively elongated to keep up with the constantly increasing width of the cardinal area. Any independent stock of *Spirifer* that can be shown to develop a syrinx will have to be distinguished under a distinct generic name to bring out its phylogenetic relations. The establishing of such genera, however, cannot be done without the best of material, and the clear evidence that the various stocks of *Spirifer* are actually not directly related phylæ. In this determination the external characters, as the presence or absence of a plicated fold or sinus, lamellose or spinose growth lines, and the nature of the plications will be of much importance.

GEORGE FREDERIC BARKER.

When the writer of the following paragraphs began the study of chemistry in 1872, his text-book was an "Elementary Chemistry," then in its tenth edition, written by Professor George F. Barker. At that time the writer never dreamed that it would be his privilege to become a colleague of this distinguished scientist, nor that later he would be called upon to write in memory of this splendid teacher, profound student, and man of noblest character.

The face of Dr. Barker was familiar to men of science, both in this country and abroad, as he made it a point, whenever possible, to meet with his fellows in science. On such occasions by his affability and courtesy he made a wide circle of friends, who in recent years have keenly felt his absence from their meetings, and were indeed shocked when the message of his death was announced. The writer had the opportunity to meet Dr. Barker daily for many years, not so intimately at first, but later with the greatest freedom and in true companionship. The impression made by him, at all times, was that of an earnest student of science, thoroughly conversant with its most recent advances and able to render subjects, which were dry and unattractive though important, so simple and so fascinating, that the ordinary layman could comprehend them with ease. His lectures to students were celebrated for their clarity of presentation as well as for their wide scope. He was painstaking in the presentation of his subject, and his constant endeavor was to make his students grasp the problems he placed before them. He spared no pains to make abstruse points clear, and if at times he seemed to demand almost too much and be a bit brusque, yet no earnest student was ever turned away; he was, in a word, the true teacher, whose sole object was the welfare of those whom he taught.

In the lecture room he had rare skill and facility as an experimenter, and one of his chief joys was to illustrate his lectures, as far as possible, with an abundance of attractive and striking experiments. He often presented the most intricate topics before large audiences, reaching sometimes into the thousands, and so uniformly brilliant was his success that he became noted throughout the country as one capable of popularizing science as few could do it. The writer recalls an occasion in his younger days, when the Academy of Music in Philadelphia was filled to its dome with an intensely interested and intelligent audience assembled to listen to his lecture on "Sound," and, while seated in the "sky parlor" of the immense auditorium, enjoying the discomforts peculiar to his position, so intensely absorbing was the lecture and its experiments that at its conclusion it was difficult for him to realize that he had actually sat there more than an hour.

Dr. Barker was much esteemed in the community where he lived by persons of all ranks. For a number of years he served on the Board of Education in the city of Philadelphia, and there exerted an influence which was entirely for the good, and never to be forgotten. His contributions to municipal interests included studies of the local water supply, of the quality of illuminating gas, and of the means for protecting public buildings from lightning. At various times he appeared as an expert in scientific matters, and in this field further demonstrated his spirit of careful investigation and absolute integrity and loyalty, as well as ability to be just and fair to all. Many of the cases called for the highest scientific knowledge and accuracy, which were abundantly supplied by him.

By his colleagues on the teaching staff of the University of Pennsylvania he was most highly valued. His services were constantly engaged upon committees, and those who worked with him in such duties entertained but one impression, to wit, that he was capable of handling the most intricate and perplexing problems with fairness, calmness, and the best judgment. Indeed, it was a pleasure to be associated with him in work of this description; his hearty coöperation and his many helpful suggestions in the solution of university problems were appreciated by all his colleagues.

Dr. Barker's early academic training was received in the Boston Public Schools, and at the academy in South Berwick, Maine. He further served an apprenticeship with Joseph Weightman, a maker of scientific instruments, going thence to the Sheffield Scientific School of Yale University, where he received the degree of Bachelor of Philosophy in the year 1858. He was deeply attached to his Alma Mater, and invariably spoke in terms of the highest praise and affection of his early teachers. His serious student days had, however, a bit of the modern in them, for if the writer remembers correctly, he was a member of the Varsity crew in the year of his graduation. Some years later, in the autumn of 1869, he became professor of Physiological Chemistry and Toxicology in the Yale Medical School, a chair created for him. During this period he served as expert for the State in several poison cases, the most noted being the Lydia Sherman case in New Haven.

His active scientific career may be said to have commenced about this time. Thus this Journal in 1867 ((2), xliii, 252) contains a brief article " Upon the Silvering of Glass," which is a modification of a suggestion of Böttger, consisting in adding to a boiling solution of Rochelle salt a solution of argentic nitrate, after which the boiling was continued for eight or ten minutes, the liquid allowed to cool, and then filtered. A second portion of the original silver solution was treated with ammonium hydroxide until the precipitate formed was almost redissolved, after which water was added and the liquid filtered. To silver glass, equal portions of these two fluids. thoroughly mixed, were poured upon it. After a lapse of about ten minutes, a brilliant layer of metallic silver was deposited. By repeating the process the layer could be thickened to any desired extent. A somewhat earlier article is entitled "Account of the Casting of a Gigantic (Rodman) Gun at Fort Pitt Foundry" (ibid., xxxvii, 296); this contains some important practical suggestions.

An interesting contribution is made by Dr. Barker, in the same Journal ((2), xliv, 263, 1867), in support of the view that formic acid is carbonous acid. He believed this to be true because of the ready formation of formic acid by the partial oxidation of carbon, and also because it resulted from the oxidation of carbonic acid. For these reasons he further concluded that formic acid was the acid of bivalent carbon.

In an extended communication "On Normal and Derived Acids," (ibid., xliv, 384), he arrived at the following conclusions:

> "1. That all the bonds of any simple radical may be saturated by the monad hydryl (OH). 2. That the compounds this formed, being evidently normal, are conveniently designated by the prefix *ortho*. 3. That the equivalence of negative radicals varies through several stages, while that of positive rarely changes, and hence, that there may be a series of ortho-acids from a given negative radical, but only a single base from a positive one. 4. That by the removal of the elements of water from a normal or ortho-acid, a derived acid is produced, which may be indicated by the prefix *meta*. 5. That when there are several such derivatives, the Greek numeral prefixes di, tri, tetra, etc., may be used to indicate the number of molecules of water removed from the ortho-acid to yield the meta-form. 6. That intermediate between the simple ortho- and the meta-acids are others containing more than a single atom of the negative radical; and that these acids may be designated by di, tri, tetra, etc. (according to the number of negative atoms) prefixed to the name of the acid, while the number of molecules of water removed from a multiple of the normal acid to form them is indicated by the same numerals prefixed to the meta. 7. That while the negative atoms in the compounds just mentioned are united by oxygen, there may be other compounds whose negative or positive atoms are united directly; thus producing a fourth class of acids and of bases.

"By classifying thus the substances known as acids and bases,—and, of course, the salts derived from them—it is hoped that their relations to each other may be made clearer. And by giving them systematic names, their position in the series may be fixed, and a step taken toward the establishment of a national nomenclature."

In 1870, appeared his text-book of "Elementary Chemistry, Theoretical and Inorganic," which ran through many editions as well as translations into other languages. This was the first book in our language in which modern chemistry was presented systematically. The style of the book, as so many can testify from its study, is concise and clear. Wolcott Gibbs spoke of it as "a book wholly in the spirit of the most advanced thought in the science."

During his life at New Haven, he contributed a note "On the spectrum of an Aurora which appeared at New Haven, November 9, 1871." The point of particular interest in this observation was the fact that the line of wave-length, 502, was not laid down in any authority accessible to the observer, as having been noted in the spectrum of the aurora. He adds: "Indeed, no previous observer, so far as I know, has seen any auroral line between the Frauenhofer lines *b* and F" (this Journal (3), ii, 465, 1871). Sometime later, he presented a second contribution "On the Spectrum of an Aurora of October 24, 1872." This aurora, like that of 1871, was distinguished by its radiant crimson color, and by its form. Dr. Barker remarks that in the lines that appeared in the spectrum, none was new, though no previous observer had seen all of them at once. Vogel had seen five and four had been seen by Dr. Barker. Two of the lines nearly coincided with the solar lines F and G, but a considerable difference was observed in the spectrum of this aurora and that of 1871, for three lines of the aurora of 1872 had no corresponding line in the spectrum of the aurora of 1871.

Dr. Barker was assistant to Dr. Bacon in the Harvard Medical School from 1859 to 1861; Professor of Chemistry in Wheaton College, Illinois, 1861; then in the Albany Medical College, where he received the degree of Doctor of Medicine (1862–1863), making while there a chemical examination of the viscera of a dead body, the first time it had ever been done in this country; next, in the University of Pittsburg (1863); he also delivered the lectures on Chemistry at Williams College in the years 1868 and 1869; and, after service in his Alma Mater, to which reference has already been made, he became Professor of Physics in the University of Pennsylvania (1872), where the remainder of his life was spent. At this period he published a contribution of considerable length, with the aid of illustrations, on "A New Vertical Lantern Galvanometer," in which claim is made for the general principles of construction of the instrument, and the advantages possessed by it in the readiness with which it could be put into use, the brilliancy of the illuminated circle of light which it gave upon the screen, its great range of delicacy by which all experimental requirements might be answered, and, finally, the satisfactory character of its performance as a demonstration galvanometer (Proc. Amer. Phil. Soc., xiv, 440). This was followed by a communication "On the Measurement of Electromotive Force (ibid., xx, 649), in which the author states: "Having had occasion to make measurements of electromotive force by the method of comparison, I have been led to devise a form of standard cell, which appears to have advantages over others heretofore used as to justify me in bringing it before the Society."

In 1880, before the American Association for the Advancement of Science, at its Boston meeting, Dr. Barker, as retiring President, delivered an address upon "Some Modern Aspects of the Life-Question," from which the following paragraphs are introduced:

"As Preston has suggested, if we regard this ether as a gas, defined by the kinetic theory that its molecules move in straight lines, but with an enormous length of free path, it is obvious that this ether may be clearly conceived of as the source of all the motions of ordinary matter. It is an enormous storehouse of energy, which is continually passing to and from ordinary matter, precisely as we know it to do in the case of radiant transmission. When potential energy becomes kinetic, the ether loses and the matter gains motion. When kinetic energy becomes potential, the lost energy of the matter is the motion gained by the ether. Before so simple a conception as this, both potential energy and action at a distance are easily given up. All energy is kinetic energy, the energy of motion. Giving now to the ether its storehouse of tremendous power, and giving to it the ability to transfer this power to ordinary matter upon opportunity, and we have an environment compared with which the strongest steel is but the breath of the summer air. In presence of such an energy it is that we live and move. In the midst of such tremendous power do we act. Is it a wonder that out of such a reservoir the power by which we live should irresistibly rush into the organism and develop the transmitted energy which we recognize in the phenomema of life? Truly, as Spinoza has put it, 'Those who fondly think they act with free will, dream with their eyes open.'"

"Such are now the facts and theories to be found in the science of to-day considering the phenomena of life. Physiologically considered, life has no mysterious passages, no sacred precincts into which the unhallowed foot of science may not enter. Research has steadily diminished day by day the phenomena supposed vital. Physiology is daily assuming more and more the character of an applied science. Every action performed by the living body is sooner or later, apparently, to be pronounced chemical or physical. And when the last vestige of the vital principle as an independent entity shall disappear from the terminology of science, the word "Life," if it remain at all, will remain only to signify, as a collective term, the sum of the phenomena exhibited by an active organized or organic being."

In following the career of our friend there is plainly seen a versatility on his part, as well as a keen interest for other branches of science than that one to which he gave the best years of his life. Thus, he is found a member of an expedition to Rawlings, Wyoming, for the purpose of reporting "On the Total Solar Eclipse of July 29, 1878"; his particular duty being to observe with an analyzing spectroscope the presence, either of light, or of dark (Fraunhofer), lines in the spectrum of the corona. (See Proc. Amer. Phil. Soc., xviii, 1880.) Again, in connection with Professor Rowland, he reported "On the Efficiency of Edison's Electric Light." See this Journal (3), xix, 337.

Dr. Barker was the first person to exhibit radium in this country (1894) after its isolation by Madame Curie in Paris. Radio-activity appealed so strongly to him, that it is not surprising to find a paper of his on "Radio-activity of Thorium Minerals" in this Journal ((4), xvi, 161, 1903). In this communication, the author introduces a number of original contributions. He repeated the experiments of Hofmann and Zerban, relative to the radio-activity of Brazilian monazite, which contains no uranium, and confirmed the results of these observers, to wit: that the thorium from this monazite is probably radio-active. From a series of experiments, he further concluded that thorium is a primary radio-active substance, and added that the thorium emanation rapidly decays, falling to one-half its value in one minute, while that of the radium emanation retains its active properties for several weeks. On the other hand, the excited radio-activity produced by the former emanation is much more prominent than that produced by the latter. Since excited radio-activity can be produced on bodies if the emanation be present, even in the absence of a radio-active substance, and since the amount of effect is directly proportional to the amount of emanation, it follows, first, that the production of excited radio-activity is a property of the emanation, and, therefore, is also produced in bodies where the radio-active emanations from thorium and radium are present: and second, that uranium and polonium, which do not give forth any emanation, do not possess the power of exciting radio-activity. In the present view of science, therefore, it would not be probable that the radio-activity of thorium is a secondary or excited radio-activity due to the uranium associated with it in the minerals previously named."

A very instructive address upon "Radio-activity in Chemistry" was delivered by Dr. Barker before the Chemical Society of Columbia University; it appeared in full in the School of Mines Quarterly (xxiv, 267). It has historical value, and will prove helpful to all wishing to familiarize themselves with the subject. It is accompanied with bibliographies covering 90 titles by the most prominent investigators in this particular field of research. In 1899, Harper and Bros. issued a small volume of 75 octavo pages on "Röntgen Rays," in which are incorporated memoirs by Röntgen, Stokes, and J. J. Thomson, translated and edited by Dr. Barker.

On the 27th of May, 1893, the American Philosophical Society celebrated the 150th anniversary of its foundation, on which occasion Dr. Barker offered a paper on "Electrical Progress since 1743." This paper is a review of the advances in Physics since that early date, emphasizing in particular the contributions to electrical science by such persons as the immortal founder of the Society, Benjamin Franklin, and by Kinnersley, Robert Hare, Joseph Henry, Joseph Saxton, David Rittenhouse, and Alexander D. Bache. "The labors of these men have mightly contributed to advance the development of scientific thought throughout the world, and so to bring about that exceptional evolution of electrical facts and theories which is the distinguishing feature of the science of the nineteenth century." This little brochure is indeed worthy of study by every student of the physical sciences.

Still other communications of Dr. Barker are "On the Henry Draper Memorial Photographs of Stellar Spectra" (Amer. Phil. Soc. xxiv, p. 166), "On the Use of Carbon Bisulphide in Prisms," (this Journal (3), xxix, 269), in which communication there is presented to the public the observations of his friend, Dr. Henry Draper, taken from the notes of the latter after his death; and "The Microphone of Hughes" (ibid. (3), xvi, 60), in which Dr. Barker takes occasion to say that the results obtained by Hughes had been clearly anticipated by more than a year by those of Edison.

Biographical memoirs of Frederick Augustus Genth, of Henry Draper, of John William Draper, and of M. Carey Lea were written for the National Academy by Dr. Barker, and he also prepared for the Smithsonian Institution annual reports upon Physics from the year 1881 to 1885, inclusive. These amount to 253 pages and represent the most recent advances in the science during these years.

From 1868 to 1900 he was associate Editor of this Journal, and the abstracts of chemical and physical papers which he contributed regularly during this period are remarkable for their clearness and accuracy. In 1874–75 he was Editor of the Journal of the Franklin Institute.

In 1892 appeared his "Physics, Advanced Course" from the press of Henry Holt & Company, which immediately met with a most hearty reception and became a standard among the text-books on this important subject.

It follows naturally that to one so active in the scientific world there should have been awarded numerous honors. Thus, in 1881, Dr. Barker was United States Commissioner to the Paris Electrical Exhibit, a delegate to the Electrical Congress, and Vice-President of the Jury of Awards, receiving the decoration of Commander of the Legion of Honor in France; in 1884, he was United States Commissioner to the Electrical Exhibit in Philadelphia; and in 1893, a member of the Jury of Awards of the World's Columbian Exposition. He was an active member of the National Academy of Sciences, serving on many of its important committees, and also of the American Association for the Advancement of Science, of which he was Vice-President twice, delivering on one of these occasions an address on "The Molecule and the Atom," a most valuable contribution to theoretical chemistry, and President in 1879; his presidential address in 1880 has already been referred to. He was a corresponding member of the British Association. He was President of the American Chemical Society (1891), the subject of his presidential address being "The Borderland between Physics and Chemistry." He was Secretary and later a Vice-President of the American Philosophical Society from 1899 until 1909. He was a member of the Physical Society and of the Deutsche Chemische Gesellschaft. In 1899 he became an honorary member of the Royal Institute of Great Britain. He was the recipient of the following academic honors: Doctor of Science from the University of Pennsylvania in 1898; LL.D from Allegheny College in 1898; and LL.D from McGill University in 1900.

He became Emeritus Professor of Physics in the University of Pennsylvania in 1900. He was a member of the Century Club of New York and the University Club of Washington.

In 1861, Dr. Barker was married to Mary M. Treadway of New Haven, Conn., who with three daughters survive this devoted and loving husband and father.

Dr. Barker was born at Charlestown, Mass., July 14, 1835, and died at Philadelphia on May 24, 1910. His was a beautiful life, so full of service to his fellow-men and so rich in its achievements that it will ever remain a most precious memory to his many friends.

EDGAR F. SMITH.

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VOL. XXX. OCTOBER, 1910.

Established by BENJAMIN SILLIMAN in 1818.

THE
AMERICAN
JOURNAL OF SCIENCE.

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FOURTH SERIES

VOL. XXX—[WHOLE NUMBER, CLXXX.]

No. 178—OCTOBER, 1910.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIV.—*On the Nature of the Ionization Produced by a Rays;*[*] by FRANK E. WHEELOCK.

[Contributions from the Sloane Physical Laboratory of Yale University.]

WHEN a gas is ionized by *a* rays, it is well known that saturation is obtained only when a large potential gradient is applied between the plates of the ionization chamber. This is much larger than would be necessary if the lack of saturation were due to general recombination of the positive and negative ions formed, if they are distributed throughout the volume of the gas.

Bragg and Kleeman[†] have explained the lack of saturation experimentally obtained, on the hypothesis of "Initial Recombination"; the two ions made by corpuscular dissociation of a molecule, situated initially in the immediate vicinity of each other, are able to recombine and thus escape the electrode placed to receive them. On this hypothesis, lack of saturation would depend upon the number of ions formed per c.c. in a unit of time; it would be independent of the size and shape of the ionization chamber; saturation would be easier with diminished pressure, and "Initial Recombination" would be greater in the more complex gases.

The experiments of Bragg and Kleeman show the above facts and "Initial Recombination" seem to be a reasonable explanation of the lack of saturation at low voltages.

Kleeman[‡] has shown that "Initial Recombination" is practically absent in air ionized by X rays and is very small in gases ionized by β and γ rays. These ionizing agents seem to effect a complete separation of the negative ions from their parent molecules. He has shown that lack of saturation for weak ionization with α rays is not due to diffusion of ions, nor does it depend upon α, the coefficient of recombination. "Initial Recombination" is greater the slower the velocity of the ionizing α particle, which probably means, the slower the velocity of the α particle the less the velocity of the ejected electron.

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[*] A Thesis presented for the degree of Doctor of Philosophy at Yale University, June, 1910.

[†] On the Recombination of Ions in Air and other Gases, Phil. Mag., xi, 1906.

[‡] Recombination of Ions, made by *a*, *β*, and *γ* rays, Phil. Mag., xii, p. 273, 1906.

Moulin[*] has interpreted the lack of saturation on the hypothesis suggested, by Langevin, that in the case of ionization by α rays, where the number of ions produced by each α particle is very great, the ions produced are not at all uniformly distributed in the volume of the gas, but are distributed, at least initially, in columns along the trajectory of the α particle.

The ordinary recombination obtained between ions of the same column ought to exceed many times that which would be obtained for the same number of ions distributed throughout the volume. According to this hypothesis, recombination should be greater when the field is applied along the path of the α particle than when it is at right angles to the path. The parallel field would not break up the columns, while the perpendicular field would produce a separation of the positive and negative ions, by breaking each column up into two.

Moulin obtained saturation at about 200 volts per cm. when the field was applied at right angles to the path, while from 1200 to 1500 volts per cm. were necessary for the parallel field. He also found that saturation was more easily obtained when the pressure was decreased.

In a second paper[†] Moulin describes some experiments using CO_2 and H_2 instead of air, and obtained results which confirm those of his previous paper. He also applied a field inclined at an angle of 45° to the path of the α particle and obtained curves which were in good agreement with those obtained by calculation.

Moulin therefore concludes that the "Initial Recombination" effect is negligible in comparison with that of general recombination (αn^2) within the columns.

For volume ionization, general recombination depends upon N, the number of ions per c.c. If the ions are formed in columns, the density of ionization within the columns would be very great, since the ions would occupy only a very small fraction of the total volume of the chamber.

It would be expected, therefore, on this hypothesis, that recombination would be different at different parts of the range of the α particle, being greatest where the maximum number of ions is produced by the α particle.

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[*] Ionization of Gas by α rays and Hypothesis of Initial Recombination, Le Radium, May, 1908.

[†] Comptes Rendus, June, 1909.

On the hypothesis of "Initial Recombination" it would be expected that recombination would be less in the part of the range where the velocity of the *a* particle is greater, since the electron would probably be ejected with greater velocity and thus have more chance to escape the remaining positive ion.

The *a* particle is a more efficient ionizing agent near the end of its path, but since it is moving slower here than when the source is nearer the chamber, more recombination would take place. This would also be the case if the lack of saturation were due to columnar ionization, because of the greater density of ions within the columns.

The purpose of the experiments here described is:—

I. (*a*) To compare the saturation curve obtained when an electric field is applied parallel to the path of the *a* particle with that obtained when the field is perpendicular to the path; (*b*) To compare the *a* ray curves with those obtained when β and γ rays are used as ionizing agents.

II. To test for the existence of columnar ionization.

III. To get a mathematical expression for the saturation curve, on the hypothesis of ionization in columns, and to compare the calculated curves with those experimentally obtained when the field is applied parallel to the path of the *a* particle.

IV. To show that the lack of agreement between the calculated and experimental curves is not due to an inclination of the columns in the ionization chamber used.

V. To compare the curves obtained with the source at different distances from the ionization chamber, for both parallel and perpendicular fields.

VI. To compare the curves obtained at different pressures in both chambers.

Description of Apparatus.

For the field parallel to the path of the *a* particle, the apparatus used (fig. 1) was similar to that of Bragg and Kleeman.

The ionization chamber, $7{\cdot}5^{cm}$ in diameter and 4^{mm} in depth, was formed of a wire gauze N, insulated from the supporting ring by small pieces of amber, and a brass plate A, insulated from the top, E, of the containing vessel by means of an ebonite plug. A second wire gauze, D, grounded through the top of the containing vessel, formed with N a second ionization chamber, which prevented stray ions from entering the ionization chamber proper.

The plate A was connected to one pair of quadrants of a Dolezalek electrometer, the second pair of quadrants being earthed. The gauze N was connected with a battery and could be charged to any desired potential. The high potential wire C was carefully screened to prevent stray ions from being carried over to the plate A. The polonium, or other radioactive substance used, was placed on a carrier, R, which could be moved up and down by means of the screw G, the position of which was given by the scale S.

The apparatus used for testing the effect of a field perpendicular to the path of the a particle (fig. 2) consisted of a brass plate, C ($8{\cdot}5^{cm}$ by $2{\cdot}5^{cm}$), connected by B to a battery, a narrow brass strip, E ($7{\cdot}2^{cm}$ by $0{\cdot}4^{cm}$), connected to one pair of quadrants of the electrometer, and a brass plate, D, surrounding E and separated from it by an air space of $0{\cdot}5^{mm}$. The plate D was grounded through the top of the containing vessel and served as a guard ring.

Fig. 1.

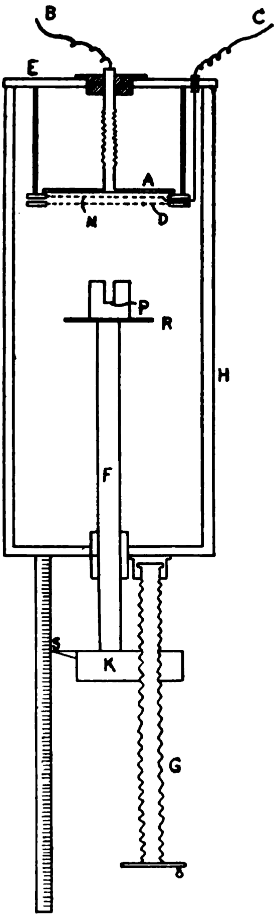
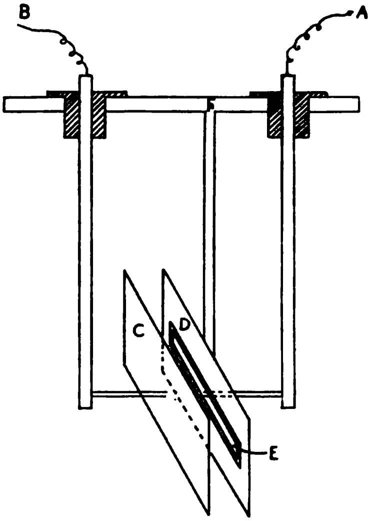


Fig. 2.



This chamber was used in the same containing vessel as that shown in fig. 1, so that the radio-active material being below, the field was perpendicular to the trajectory of the α particle.

I. (*a*) *Comparison of Curves obtained with the Field parallel and perpendicular to the Path of the α particle.*

When a gas is ionized by α rays, if the ions are formed in columns along the path of the α particle the saturation value of the current would be obtained for a much smaller potential gradient applied between the plates, when the field is perpendicular, than when it is applied along the path of the α particle. The following data show this to be true and agree with the results obtained by Moulin:

Parallel Field.

Source 2·6$^{\mathrm{cm}}$ from the middle of the chamber.

Volts/cm.	Current	% lack sat.
5	12·77	33·9
10	13·67	29·3 (1)
20	15·1	21·8 (2)
40	15·95	17·4 (3)
100	17·45	9·7
200	18·35	5·0 (4)
400	19·15	1·9
800	19·32	0·0

Perpendicular Field.

Source 2·6$^{\mathrm{cm}}$ from the middle of the chamber.

Volts/cm.	Current	% lack sat.
2	11·98	59·0
4	15·95	45·4
10	20·76	29·3 (1)
20	23·80	18·5 (2)
40	26·40	9·6 (3)
80	27·85	4·6
120	28·65	1·9
200	29·08	0·4 (4)
400	29·18	0·07
1000	29·20	0·00

Note.—For a direct comparison, see (1), (2), (3), (4), above, or fig. 3.

The saturation curves are practically the same when a positive charge is applied to the gauze of the ionization chamber as they are for a negative charge. This is true when the field is applied parallel or perpendicular to the path of the α particle.

(*b*) When a weak source of β and γ rays is used as the ionizing agent, saturation is practically obtained for a very small potential gradient applied between the plates.

Parallel Field.

Source 5·1$^{\mathrm{cm}}$ from the middle of the chamber.

Volts / cm.	Current	% lack sat.
5·0	6·95	6·0
40·0	7·0	5·4
200·0	7·2	2·7
800·0	7·4	0·0
1200·0	7·4	0·0

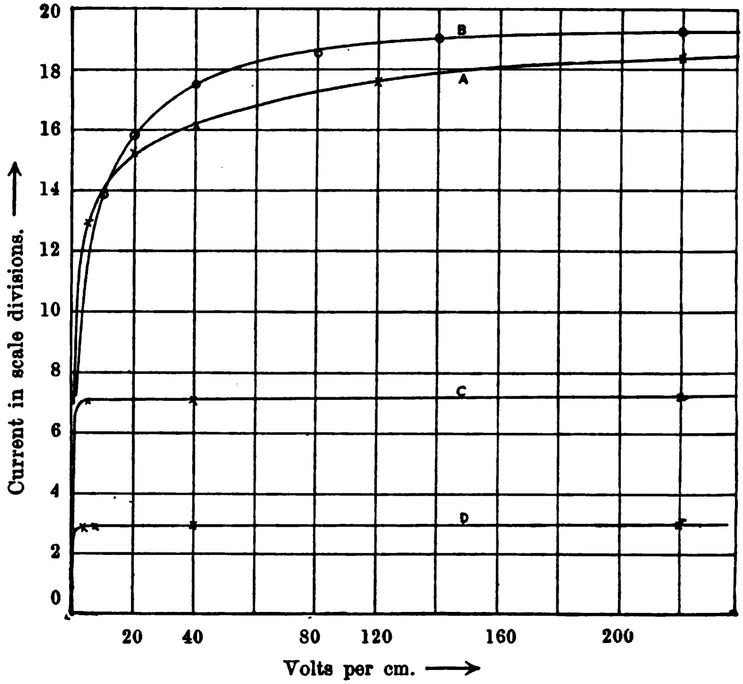
Perpendicular Field.

Source 2·7$^{\mathrm{cm}}$ from the middle of the chamber.

Volts / cm.	Current	% lack sat.
2·0	2·75	5·2
4·0	2·84	2·1
8·0	2·87	1·0
40·0	2·9	0·0
200·0	2·9	0·0
1000·0	2·9	0·0

Note.—For curves see fig. 3.

FIG. 3.



A = α ray curve, parallel field.
B = α ray curve, perpendicular field.
C = β and γ ray curve, parallel field.
D = β and γ ray curve, perpendicular field.

The fact that for β and γ rays, saturation is obtained for small potential differences between the plates, has been explained by Kleeman as due to the electron, emitted in the act of ionization, being shot off with a velocity great enough to effect complete separation from the remaining positive ion, and therefore initial recombination would be negligible.

General recombination would have very little effect in this case, since it is volume ionization from a very weak source.

II. *Evidence of Columnar Ionization.*

When a gas is ionized by β or γ rays, it has been seen that saturation is obtained at small voltages, if the ionization is small. It is found by experiment that as the ionization increases, a stronger field is necessary to obtain the saturation value.

In the case of ionization by β rays, the ions are distributed throughout the volume of the gas, and general recombination, which depends upon the number of ions per c.c. in the gas, would be greater as the ionization is increased. It would not be expected that the ratio of the currents obtained with two sources of different intensities would be the same for different potential gradients. This is in accord with the ordinary theory of volume ionization and with all experiments hitherto made on ionization produced by β, γ, and Röntgen rays.

On the other hand, when a gas is ionized by α rays, if the ions are formed in columns along the path of the α particle, an electric field applied along the path, that is along the axis of the column so formed, would not break up the column and the recombination occurring would be between ions belonging to the same column. It would be expected that the ratio of the currents obtained with sources of different intensities would be constant for different potential gradients applied, since each α particle makes the same number of ions in its path, and the density of ionization would be the same in any one column.

When the field is applied at right angles to the direction of the column, each column would be separated into two, one of positive and the other of negative ions.

With the perpendicular field two cases present themselves: first when the source is so weak that there are very few α particles given off; second, when a stronger source is used.

In the first case, very few columns would exist in the ionization chamber during the time required for the ions present to be carried over to the receiving plate by the electric field. The ions of one column would have little chance to recombine with those of another in going across the chamber.

In the second case, with the stronger source, enough columns might exist in the chamber at any one time, so that the ions of one column would, when the field is applied, come within the sphere of influence of those of the opposite sign from another column. Recombination might then take place not only between ions of the same column but between those of different columns.

In this case the ratio of the currents obtained with a given field would not be constant, because of the added recombination of ions of different columns, which would vary with the number of columns present in the chamber.

To apply this test for the existence of ions in columns it is necessary to obtain curves from sources of different intensity, with both parallel and perpendicular fields.

(*a*) Curves were obtained with the radio-active source bare and when covered with a wire gauze to cut out part of the α particles. The density of ionization would be the same wherever ions exists, i. e., within the columns.

Parallel Field. Source 2·6^{cm} from the middle of the chamber.

Volts / cm.	Current: Without gauze	Current: With gauze	Ratio of Currents
5	7·7	3·13	2·46
10	8·35	3·35	2·5
20	9·12	3·59	2·54
40	9·65	3·76	2·57
100	10·6	4·2	2·52
200	11·2	4·51	2·48
400	11·5	4·7	2·45

Perpendicular Field.

Source 2·6^{cm} from the middle of the chamber.

Volts / cm.	Current: Without gauze	Current: With gauze	Ratio of Currents
2·1	9·88	5·25	1·88
4·2	13·25	6·5	2·04
10·6	17·33	7·82	2·22
21·0	20·0	8·85	2·26
43·0	22·2	9·62	2·31
85·5	23·6	9·95	2·37
126·0	23·8	10·05	2·38
168·5	24·0	10·12	2·38
211·5	24·1	10·14	2·38

The ratio of currents is approximately constant for the parallel field but increases with the potential gradient for the perpendicular field; this is as would be expected if the ions are initially formed in columns. For the perpendicular field the ions of one column might interfere with those of another.

(*b*) Two specimens of polonium were then used, one of which was about twenty-nine times as strong as the other, and the following data were obtained:

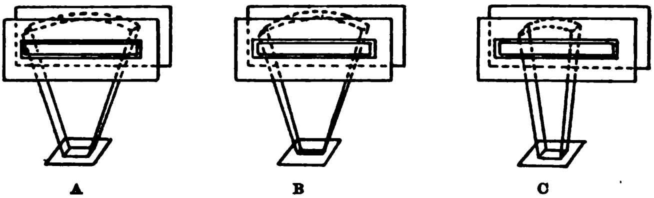
Parallel Field. Source 2·6^{cm} from the middle of the chamber.

Volts / cm.	Current: Weak Polonium 3 min. readings	Current: Strong Polonium 1 min. readings cap. 196·46 added	Ratio of Currents	Ratio for 3 min. readings without cap.
5·25	1·39	6·82	4·9	29·4
20·9	1·63	8·0	4·9	29·4
42·5	1·75	8·55	4·89	29·34
86·3	1·91	9·42	4·93	29·58
196·3	2·08	9·85	4·73	28·4
355·0	2·15	10·1	4·7	28·2

Again the ratio of deflections is approximately constant.* This could not be so if volume ionization existed, since the density of ionization in the one case would be twenty-nine times the density in the other, and general recombination would have a very different effect in the two cases.

(c) Experiments were then made with the field at right angles to the path of the a particle, in which fan-shaped beams of different sizes and shapes were used. These were obtained by placing slits of different dimensions over the source. The different beams used were as shown in fig. 4.

Fig. 4.



Slit $5 \times 0{\cdot}5^{\mathrm{mm}}$ — Slit $5 \times 0{\cdot}2^{\mathrm{mm}}$ — Slit $0{\cdot}5 \times 1{\cdot}5^{\mathrm{mm}}$

Perpendicular Field.

Source 2·6 cm. from the middle of the chamber.

	Current			Ratio of Currents		
Volts / cm.	A Slit $5 \times 0{\cdot}5^{\mathrm{mm}}$	B Slit $5 \times 0{\cdot}2^{\mathrm{mm}}$	C Slit $0{\cdot}5 \times 1{\cdot}5^{\mathrm{mm}}$	A/B	A/C	C/B
2·1	9·88	2·57	3·7	3·84	2·67	1·44
10·6	17·33	3·35	5·36	5·17	3·23	1·6
21·0	20·0	3·65	5·77	5·48	3·47	1·58
43·0	22·2	3·9	6·29	5·7	3·53	1·61
85·5	23·6	4·07	6·56	5·8	3·58	1·61
211·5	24·1	4·15	6·68	5·8	3·6	1·61

From the above data it will be seen that the ratio of the currents C/B is practically constant. The ionization in both of these cases is small and the result appears to indicate that there are not enough columns in the chamber at any time to get interference of the ions of one column with those of another.

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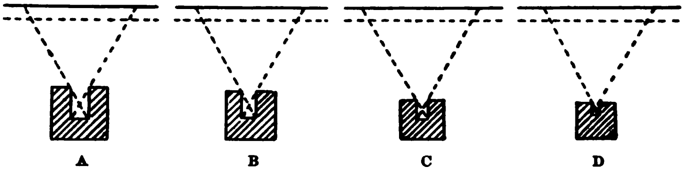
* It is interesting to observe, that to compare the ionization produced by a rays from different sources, it is not necessary to obtain the saturation value of the current. This is very convenient, since for ionization by a rays saturation is obtained only when the potential difference between the plates is very large, when the field is applied parallel to the path of the a particle.

The current obtained with the beam A is much larger than that with either B or C. The ratios A/B and A/C are not constant. This looks as if, with beam A, enough columns do exist to give interference of the ions between columns and consequently more recombination occurs.

(*d*) A further test for columnar ionization was made as follows: the radio-active source was covered by hollow cylinders of different diameters and heights. The source was kept at a fixed distance ($2 \cdot 6^{cm}$) from the chamber and the internal dimensions of the hollow cylinders were varied so that the area of the plate receiving ions was constant in all cases, as shown in fig. 5.

FIG. 5.



The internal dimensions of the cylinders are given below.

	Diameter	Height
A	5^{mm}	$7 \cdot 5^{mm}$
B	4	6·0
C	3	4·5
D	2	3·0

The following data were obtained:

Parallel Field.

Source $2 \cdot 6^{cm}$ from the middle of the chamber.

Volts/cm	Current Cylinder $5 \times 7 \cdot 5^{mm}$	Current Cylinder 4×6^{mm}	Ratio of Currents
5·4	8·33	6·68	1·25
21·5	9·78	7·87	1·24
107·5	11·4	9·12	1·25
427·5	12·38	9·8	1·26
1252·5	12·62	10·03	1·26

Volts/cm	Cylinder $3 \times 4 \cdot 5^{mm}$	Cylinder 3×4^{mm}	Ratio
5·43	9·02	3·87	2·3
22·5	10·68	4·37	2·4
109·5	12·63	5·25	2·4
432·5	13·6	5·63	2·4
1297·5	13·83	5·77	2·4

As before, the ratio of the currents is constant, as would be expected if the ions are formed in columns.

(*e*) The active deposit from thorium was also used as an ionizing agent. This was obtained in the usual way by putting thorium hydroxide in a closed metal dish, through the top of which a small brass plug was placed. The containing vessel was charged positively and a difference of potential of about 300 volts was maintained between the vessel and the plug.

The deflections were corrected for the decay of the excited activity.

The plug was exposed for different lengths of time and the following data were obtained:

Parallel Field.

Active deposit 3·5^{cm} from the middle of the chamber.

	Current		Ratio
Volts/cm	27 hrs. Exposure	51 hrs. Exposure	of Currents
5·3	1·62	2·16	1·33
21·8	1·82	2·37	1·3
104·8	1·95	2·68	1·37
488·8	2·09	2·91	1·39
1013·8	2·17	3·0	1·38

The activity was tested at two different times during its decay with the following results:

Parallel Field.

Active deposit 3·5^{cm} from the middle of the chamber.

	Current		Ratio
Volts/cm	65 hrs. Exposure	After 6·5 hrs.	of Currents
5·25	1·82	0·94	1·93
21·8	2·0	1·12	1·8
102·5	2·28	1·15	1·98
413·8	2·39	1·27	1·88
1036·0	2·40	1·29	1·86

The ratio is again constant when the field is applied parallel to the path of the α particle. The above deflections are not corrected for ionization due to the β and γ rays of thorium B, but this is so small that it will have no appreciable effect.

Experiment, therefore, seems to justify the assumption that in the case of ionization by α rays, ions are formed in columns along the path of the α particle. These columns are not broken up by the parallel field, but are when the field is at right angles to the path.

III. *A Theoretical Expression for the Saturation Curve.*

A theoretical expression for the saturation curve may be obtained as follows, on the hypothesis of the ions being formed in columns along the path of the α particle and a uniform distribution of ions in the columns.

Let N be the number of positive ions
generated by one α particle
in the chamber.
n_0 be the number of positive ions per c.c.
a be radius of a column.
b be depth of ionization chamber.

The time for an ion to go from any position, x, to the top plate is given by

$$t=\frac{b-x}{k\overline{X}}\quad\text{where } k=\text{mobility of the ion and } \overline{X}=\text{electric force.}$$

Limiting time for any ion to have a chance to recombine is

$$1/2\,\frac{b}{k\overline{X}}\quad\text{since half of the ions are going each way.}$$

Limiting time during which an ion at x can recombine is

$$1/2\,\frac{b-x}{k\overline{X}}$$

Since the α particle passes through the chamber almost instantaneously, the ionization is over immediately

and $$-\frac{dn}{dt}=an^2$$

whence $$\frac{1}{n}-\frac{1}{n_0}=at.$$

Therefore, for an ion which starts at x, the final density n_x', that is the number of ions per c.c. which will reach the plate, will be given by:

$$\frac{1}{n_x}=\frac{1}{n_0}+a\frac{1}{2}\quad\frac{b-x}{k\overline{X}}$$

The charge per column, reaching the plate, will be:

$$e\pi a^2\int_0^b n_x\,dx$$

$$=\pi a^2 e\int_0^b\frac{2n_0k\overline{X}}{(2k\overline{X}+an_0b)-an_0x}\,dx$$

or $$Q_{\overline{X}} = \pi a^2 e \, \frac{2k\overline{X}}{\alpha} \log \frac{2k\overline{X} + \dfrac{\alpha N}{\pi a^2}}{2k\overline{X}} ; \quad \left\{ \begin{array}{l} \text{Since} \\ N = \pi a^2 n_0 b \end{array} \right.$$

where $Q_{\overline{X}}$ = charge per column reaching the electrode for a field $\overline{X}$.

Now let $S = \pi a^2$ = cross section of a column and $g = \dfrac{2k\overline{X}}{\alpha}$;

The above expression reduces to

$$Q_{x} = e g s \log \left(1 + \frac{N}{gs} \right) \text{.........} \quad (B)$$

If columnar ionization is to explain completely the lack of saturation obtained when a gas is ionized by α particles, the theoretical curve should fit the experimental curve.

Comparison of the Experimental Curve with that given by Equation (B).

Volts / cm.	Current obtained by experiment with the parallel field. Source 2·6$^{\text{cm}}$ from chamber.	Current calculated from Equation B, made to fit experimental curve at 0·25 volts / cm. and at saturation.
0·25	1·70	1·70
0·75	4·58	3·44
2·02	6·66	5·73
4·80	7·79	7·90
10·13	8·28	9·45
20·75	9·00	10·48
42·00	9·49	11·10
105·75	10·49	11·46
209·50	10·91	11·67
419·50	11·21	11·72
840·50	11·43	11·75
1260·75	11·80	11·77

For curve see fig. 6.

It is seen from the data or from the curves, fig. 6, that except for a potential gradient below 5 volts / cm., the theoretical curve lies above the experimental and approaches saturation faster. Calculations were made for several curves and the above was always found to be the case.

In the ionization chamber used (the ordinary Bragg chamber), the lines of electric force would not be strictly parallel to the path of the α particle so that there would be the combined effect of the field resolved along and at right angles to the path of the *a* particle and less recombination might be expected with small differences of potential between the plates.

Fig. 6.

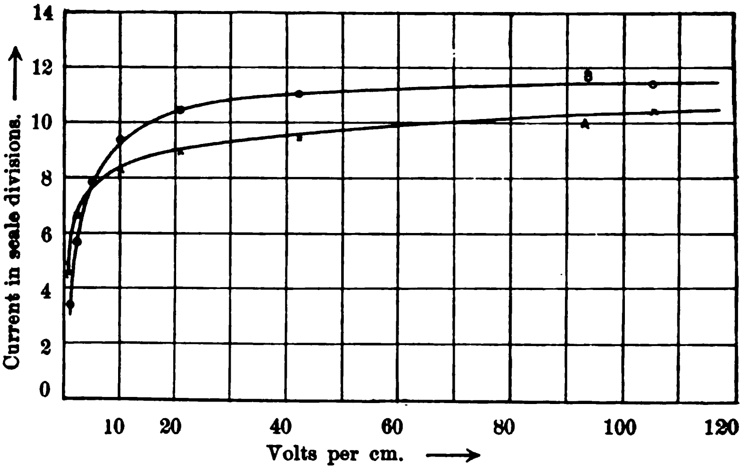


Fig. 6.—A, Experimental curve. B, Calculated curve.

This suggested experiments in which the field would be strictly parallel to the trajectory of the *a* particle.

IV. *To Test the Effect of Inclination of the Columns.*

For these experiments the ordinary Bragg chamber, used above, was replaced by an ionization chamber consisting of a spherical brass cap of radius 3^{cm} for an upper plate, a spherical cap of wire gauze, radius $2{\cdot}6^{cm}$, for the lower plate of the ionization chamber. This with another spherical gauze cap, radius $2{\cdot}2^{cm}$, formed a second ionization chamber which prevented any stray ions from getting into the ionization chamber proper. The caps were placed 4^{mm} apart. The radio-active source was placed at the center of the spheres of which the caps were a part and only a small pencil of rays was used.

The curves obtained with the spherical chamber, in which the field was always parallel to the path of the *a* particle, differ very little from those obtained with the Bragg chamber; however they do show slightly more recombination at low voltages, which would be expected. The experimental curve was found to lie below the calculated curve except when an intense electric field was applied.

The explanation of the discrepancy between the experimental curve and that given by the equation is not, therefore, the lack of parallelism between the field and the columns.

This discrepancy may be due to the fact that in the theory above given, it was assumed that uniform distribution of the ions existed in the columns themselves, which is probably not the case. It would be expected that the density of ions would be greater along the axis of the column and would fall off with the distance according to some law, which, if known, would give a theoretical curve, that might more nearly and perhaps exactly fit the experimental curve.

On the other hand, it is quite possible that "initial recombination" (in the sense used by Bragg) may account for part of the lack of saturation, and that the final explanation may require both the "initial recombination" and "columnar ionization" hypotheses.

V. *Comparison of the curves obtained when the ions are produced at different parts of the range of the a particle.*

Since the velocity of the *a* particle increases as the distance from the source decreases, it is probable that the ejected electron would be sent farther away from its parent molecule when the ionizing source is near the chamber than when it is farther away; that is, the greater the velocity of the ionizing *a* particle, the greater the velocity of the ejected electron.

If this be true, it would be expected, according to Bragg's initial recombination hypothesis, that the amount of recombination would be greater when the ions are produced in the part of the range where the velocity of the *a* particle is less.

According to the hypothesis of columnar ionization, recombination would be greatest in the part of the range where the greatest ionization per column is obtained.

The following data were obtained with the source at different distances from the ionization chamber:

Parallel Field.

	$3{\cdot}5^{cm}$		$2{\cdot}6^{cm}$		$1{\cdot}9^{cm}$	
Volts/cm.	Current	% lack	Current	% lack	Current	% lack
5	4·95	35·9	12·77	33·9	11·35	30·2
10	5·37	30·5	13·67	29·25	12·35	24·1
20	5·87	24·2	15·10	21·8	13·15	19·2
40	6·32	18·6	15·95	17·4	13·95	14·3
100	6·77	12·4	17·45	9·7	15·0	7·8
200	7·15	7·5	18·35	5·0	15·45	5·0
400	7·55	2·3	19·15	1·9	16·0	1·7
800	7·70	0·6	19·32	0·0	16·27	0·0
1200	7·75	0·0	----	----	----	----

For curves see fig. 7.

Volts/cm.	Per cent lack of saturation Dist. 3·5cm	2·6cm	1·9cm
5	35·9	33·9	30·2
10	30·5	29·2	24·1
20	24·2	21·8	19·2
100	12·4	9·7	7·8
400	2·3	1·9	1·7

FIG. 7.

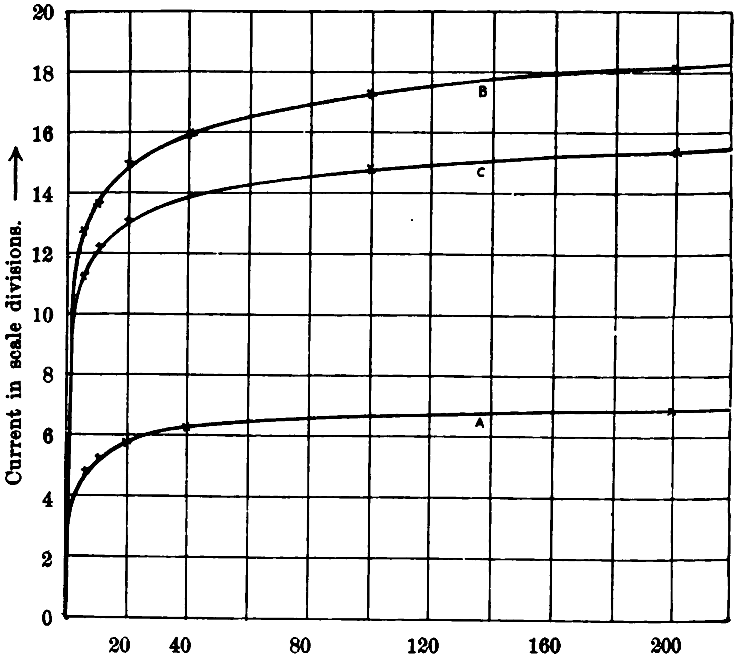


FIG. 7.—A, Source at 3·5cm. B, Source at 2·6cm. C, Source at 1·9cm.

It will be noticed that with the polonium 3·5cm from the middle of the ionization chamber, that is, nearly out of range, the percentage lack of saturation is greatest; at 1·9cm it is least, and at 2·6cm an intermediate value is obtained.

Assuming Bragg's initial recombination hypothesis, this can be explained as follows: The electrons emitted in the act of ionization would be sent farther away from the parent molecules when the source is 1·9cm from the ionization chamber than when the distance is either 2·6cm or 3·5cm. The electrons would thus have a greater chance of getting out of the sphere of influence of the remaining positive ions, with the ionizing source at 1·9cm from the chamber, than in either of the other cases.

On the hypothesis of ionization in columns, it would be expected, since the density of ionization is greater when the polonium is 2·6$^{\text{cm}}$ fron the chamber, that recombination would be greater. Experiment shows greater recombination with the ionizing source at 2·6$^{\text{cm}}$ than at 1·9$^{\text{cm}}$, but less recombination than when it is at 3·5$^{\text{cm}}$. However, when the source is 3·5$^{\text{cm}}$ from the ionization chamber, some of the α particles (those sent off at angles of from 23·2° to 26·6° with the vertical) do not enter the chamber at all, and most of the ions in the chamber are formed by the α particles which are sent off, making very small angles with the vertical. The columns thus made would be very little broken up by the component of the electric force at right angles to the path of α particles, since this component would be small.

When the source is 2·6$^{\text{cm}}$ or 1·9$^{\text{cm}}$ from the middle of the chamber all of the α particles cross the ionization chamber, and the perpendicular component of the electric force might have an appreciable effect upon the recombination of ions, since the columns would be more or less broken up.*

Data obtained with the perpendicular field.

	3·2$^{\text{cm}}$		2·6$^{\text{cm}}$		2·3$^{\text{cm}}$	
Volts/cm.	Current	% lack	Current	% lack	Current	% lack
2	8·75	55·3	11·98	59·0	11·1	58·9
4	11·19	42·8	15·95	45·4	15·23	43·7
10	14·1	28·5	20·76	29·3	19·65	27·3
20	16·05	18·0	23·8	18·5	22·43	17·1
40	17·87	8·7	26·4	9·6	24·6	9·05
80	18·6	4·96	27·85	4·6	25·93	4·1
120	19·1	2·4	28·65	1·9	26·6	1·7
200	19·5	0·36	29·08	0·41	26·95	0·37
1000	19·57	0·0	29·2	0·0	27·05	0·0

For curves see fig. 8.

Mean value of % lack of saturation from several curves.

Volts/cm	Dist. 3·2$^{\text{cm}}$	Dist. 2·6$^{\text{cm}}$	Dist. 2·3$^{\text{cm}}$
2	55·6	59·6	58·3
4	43·3	45·9	44·0
10	28·0	30·0	27·9
40	9·1	10·3	8·8
80	4·8	5·1	4·0

By comparing the lack of saturation at the distances given in the above table, it will be seen that more recombination takes place when the source is 2·6^{cm} from the chamber than in either of the other cases.

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* A better test would have been possible if α particles of longer range than those from polonium had been used, but the thorium I had was too weak and Ra. C decays too rapidly for saturation measurements, which take considerable time.

This is as would be expected on the hypothesis of ionization in columns. At 2·6^{cm} the density of ions in the columns is greatest, and therefore greater recombination would take place. With the source at 2·3^{cm} from the chamber the ionization is a little less than at 2·6^{cm}; that is, the density of ions in the columns is slightly less and the percentage lack of saturation is correspondingly smaller. With the source at 3·2^{cm} the current is about two-thirds that obtained with the source at 2·6^{cm} or 2·3^{cm}.

Fig. 8.

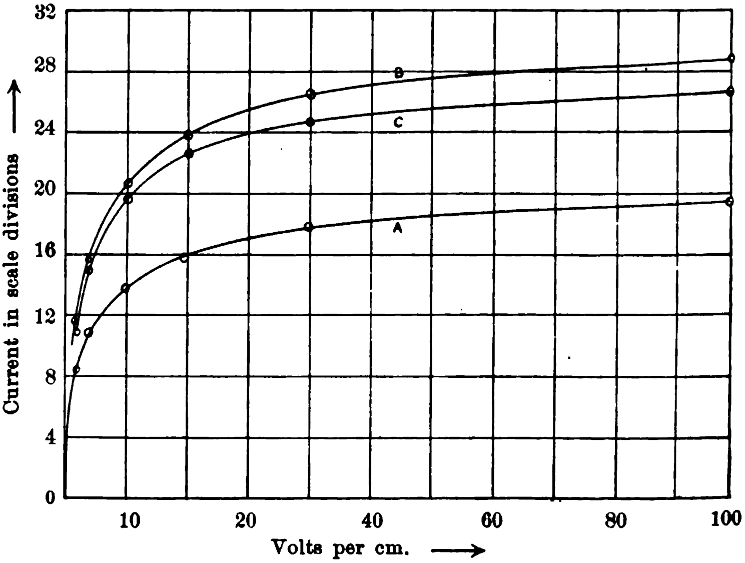

Fig. 8.—A, source at 3·2^{cm}; B, source at 2·6^{cm}; C, source at 2·3^{cm}.

This is due to the fact that some of the *a* particles just barely enter the chamber because of being shot off at relatively large angles with the vertical.

On the other hand, the initial recombination hypothesis of Bragg fails to account for the differences in the experimental curves obtained at different parts of the range, when the electric field is applied at right angles to the path of the *a* particle.

The velocity of the *a* particle is greatest with the source at 2·3^{cm}, least with the source at 3·2^{cm}, and has an intermediate value at 2·6^{cm}. The per cent of the ions recombining should therefore be least at 2·3^{cm}, greatest at 3·2^{cm}, and have an intermediate value at 2·6^{cm}, which is not the case.

Again, the effect of initial recombination, if it exists, should be the same whether the field is applied along the path of the *a* particle or at right angles to it. Experiment shows that the saturation current is obtained with a potential gradient of about 200 volts/cm. between the plates of the ionization chamber, while from 1200 to 1500 volts/cm. are necessary for saturation with the parallel field.

The results of the experiments with the ionization produced at different parts of the range of the *a* particle seem to show that neither initial recombination, nor the hypothesis of ionization in columns along the path of the *a* particle, completely accounts for the lack of saturation obtained by experiment. Initial recombination fails when the field is at right angles to the path, while columnar ionization does not entirely account for the recombination obtained with the parallel field.

Here again it is seen that both hypotheses may be needed to completely explain the lack of saturation experimentally found.

VI. *Comparison of Curves obtained at different Pressures.*

Bragg and Kleeman* found that for a gas ionized by *a* rays, saturation was obtained at a lower potential gradient when the pressure of the gas was decreased. This is as would be expected if initial recombination takes place. At higher pressures the ejected electron might not get out of the sphere of influence of the parent molecule before it is stopped by encountering another molecule; but as the pressure diminishes the mean free path of the electron is increased, and the ejected electron is then able to get farther away from the positive ion and hence initial recombination would occur less frequently.

According to the hypothesis of columnar ionization, as the pressure is diminished the density of ionization in the columns would be diminished and the amount of recombination would be less. Thus it is seen that either hypothesis might explain the results obtained by experiment.

Data obtained at different pressures:

Parallel Field.

Source 4·3^{cm} from the middle of the chamber.

	Pressure mm. mercury	Volts / cm.	Current	% lack sat.
A	544·7	5	10·4	19·1
		10	10·9	15.2
		20	11·45	10·9
		40	11·83	7·9
		100	12·5	2·7
		200	12·75	0·8
		400	12·77	0·6
		800	12·85	0·0

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* Bragg and Kleeman, Phil. Mag., xi, 1906.

	Pressure	Volts / cm.	Current	% lack sat.
B	354·	5	7·07	9·2
		10	7·21	7·4
		20	7·24	7·1
		40	7·6	2·5
		100	7·76	0·4
		200	7·79	0·0
C	224·	5	3·97	5·5
		10	3·99	5·0
		20	4·06	3·4
		100	4·11	2·1
		400	4·20	0·0

For curves see fig. 9.

Fig. 9.

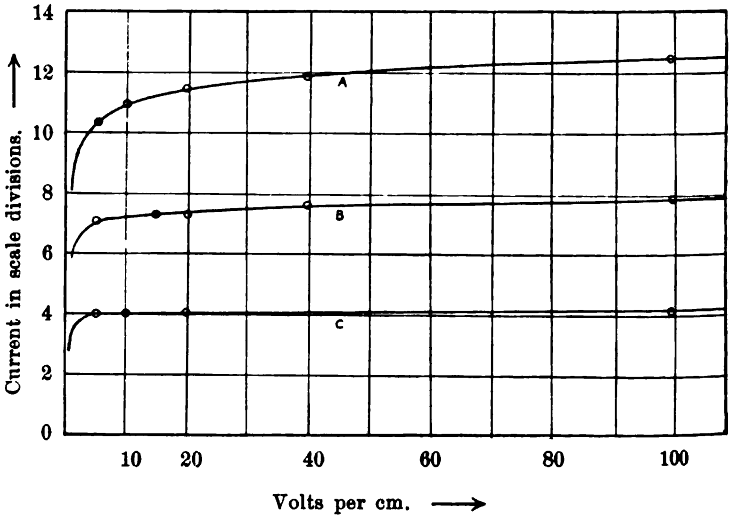

Fig. 9.—A, Pressure of 544·7^{mm} Hg. B, Pressure of 354·0^{mm} Hg. C, Pressure of 224·0^{mm} Hg.

Source 9^{cm} from the middle of the chamber.

D	224·	5	5·34	5·7
		10	5·5	2·8
		20	5·53	2·3
		100	5·66	0·0
		400	5·66	0·0

	Pressure mm. mercury	Distance from chamber	% lack saturation at different voltages		
			5	20	100
A	544·7	4·3	19·1	10·9	2·7
B	354·0	4·3	9·2	7·1	0·4
C	224·0	4·3	5·5	3·4	2·1*
D	224·0	9·0	5·7	2·3	0·0

* The large value is probably due to an experimental error.

$4·3^{cm}$ at $544·7^{mm}$ pressure corresponds to $3·08^{mm}$ at 760^{mm} pressure.
4·3 " 354·0 " " " 2·0 " 760 "
4·3 " 224·0 " " " 1·27 " 760 "
9·0 " 224·0 " " " 2·65 " 760 "

In cases A, B, and C, the percentage lack of saturation decreases as the pressure is diminished, which would be expected on either hypothesis.

In addition to the direct effect of diminishing the pressure there is an indirect effect due to the change in range of the *a* particle-producing ions. Since the range varies inversely as the pressure, diminishing the pressure and keeping the radioactive source at a fixed distance ($4·3^{cm}$) from the chamber is equivalent to bringing the source nearer the chamber. This indirect effect is small, however, compared with the effect of decreasing the number of molecules of gas in the chamber.

It is of interest to see how the curve represented by the equation, $Q_{\bar{X}} = egs \log \left(1 + \frac{N}{gs}\right)$, which was based upon the hypothesis of columnar ionization and a uniform distribution of ions within the columns, compares with the curves experimentally obtained at reduced pressures.

To make this comparison the values of gs were found, which would make the equation fit the experimental curve (pressure 761^{mm} mercury) at different potential gradients applied.

Values of $gs = \frac{2k\bar{X}}{a} \pi a^2$ were then calculated for pressures of 354^{mm} and 224^{mm} of mercury respectively, taking into account the variation of the mobility (k) of the ion, also the variation of a, the coefficient of recombination, with the pressure. The mobility varies inversely as the pressure* for the range of pressure used. The variation of a with the pressure was obtained by plotting Langevin's values of $\epsilon = \frac{a}{4\pi e(k_1 + k_2)}$, given by J. J. Thomson† and interpolating for the pressures used.

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* Alois F. Kovarik, Physical Review, April, 1910.

† Conduction of Electricity through Gases, by J. J. Thomson (second edition), p. 73.

The results obtained are shown in the following table:

Pressure 354^{mm}.

	Experimental		Calculated	
Volts / cm.	Current	% lack	Current	% lack
5	7·07	9·2	7·24	6·1
10	7·21	7·4	7·33	4·9
20	7·24	7·1	7·46	3·2
40	7·6	2·5	7·51	2·6
100	7·76	0·4	7·60	1·4
200	7·79	0·0	7·71	0·0
Pressure 224^{mm}.				
5	5·34	5·7	5·45	3·2
10	5·5	2·8	5·57	1·06
20	5·53	2·3	5·57	1·06
100	5·66	0·0	5·63	0·0

By comparing the calculated with the experimental results, it is seen that the calculated curves approach saturation more quickly than the experimental curves.

In calculating the above curves it was assumed that the radius of the columns was not appreciably affected by the diminution of pressure. If the radius of the column should vary inversely as the pressure, calculation shows that for 5 volts/cm. the lack of saturation reduces to about 1 per cent.

Although the above equation does not fit the experimental curve at atmospheric pressure, it seems allowable to use it to test the effect of changing the pressure, as has been done above.

The fact that the calculated curves for reduced pressures approach saturation more quickly than the experimental curves seems to be another reason for concluding that the effect of general recombination of the ions within the columns does not wholly account for the lack of saturation experimentally obtained, but that initial recombination in the Bragg sense has an appreciable effect.

Summary of Results.

(1) For a gas ionized by α rays the ions are formed in columns along the trajectory of the α particle. These columns are not broken up by a field applied along the axes of the columns and the positive and negative ions have to pass each other in going to the plates of the ionization chamber, while a field at right angles to the columns produces a separation of the positive and negative ions by breaking each column up into two.

(2) With the parallel field, the ionization is proportional to the intensity of the source, even when far from saturation.

(3) The equation obtained by assuming columnar ionization with the ions uniformly distributed within the columns, does not represent the curve experimentally obtained with the parallel field. The experimental curve lies below the calculated curve, except for small potential gradients, when the ordinary Bragg chamber is used.

(4) The lack of agreement between the experimental and calculated results is not due to an inclination of some of the columns in the ionization chamber.

(5) The lack of saturation obtained at different parts of the range, when the field is applied parallel to the path of the ionizing *a* particle, is not completely accounted for by initial recombination; neither does columnar ionization completely explain the results obtained with the perpendicular field.

(6) The saturation value of the current is obtained more easily as the pressure of the gas is diminished, This would be expected on either hypothesis. However, the results obtained appear to indicate that the lack of saturation is not all due to the effect of general recombination of the ions within the columns.

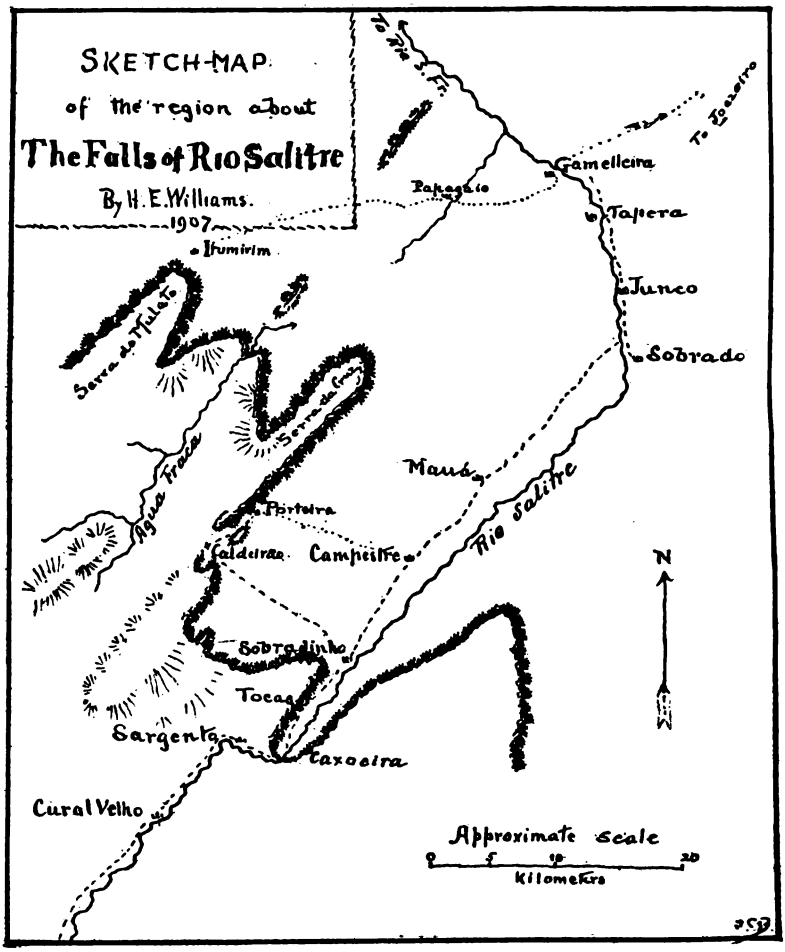
(7) Undoubtedly a considerable part of the anomalous behaviour of the ions produced by *a* rays (in respect to saturation, etc.) is due to the columnar arrangement of the ions; it is possible that this would be sufficient to account for all the facts if the distribution of the ions within the columns were known. On the other hand, it appears probable that certain outstanding discrepancies may be due to initial recombination.

In conclusion, I wish to express my gratitude to Professor H. A. Bumstead, at whose suggestion these experiments were undertaken, for his many valuable suggestions and kindly interest in the work.

ART. XXV.—*The Geology of the Serra do Mulato, State of Bahia, Brazil;** by J. C. BRANNER.

THE city of Joazeiro stands on the banks of the Rio São Francisco at the northern end of the Bahia and S. Francisco railway, 574 kilometers from the city of Bahia. The region in the vicinity of Joazeiro is remarkably flat, with here and there a

FIG. 1.



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* By permission of Prof. O. A. Derby, Director of the Serviço Geologico do Brasil.

distant isolated peak or mountain cluster rising above the otherwise even horizon line made by the low forest growth. The most prominent to be seen from Joazeiro is the Serra do Mulato, which lies about fifty-one kilometers to the southwest. The other peaks or ranges visible from Joazeiro have the rounded or irregular outlines that Brazilian geologists are accustomed to see in mountains of granite or other crystalline rocks, while the top of the Serra do Mulato is flat and the sides are precipitous, suggesting hard, horizontal beds at the top resting upon more yielding ones.

Although the Serra do Mulato is only thirty-two kilometers south of the Rio São Francisco at the village of Tatuhy, it was never visited by a geologist so far as can be learned, until Sept. 1907, when the writer made a trip to its summit in company with Dr. Alfredo de Carvalho, a Brazilian engineer of Pernambuco.

The geology of the mountain is quite simple on the whole, but taken in connection with what was subsequently learned of the region to the south and southwest, it has helped greatly to clear up our conceptions of the geology of a large area in the interior of Bahia regarding which there has long been much doubt and uncertainty.

The region between Joazeiro and the Serra do Mulato is quite flat, and, with the exception of a few small glades and a few cultivated fields, is covered with the short scrubby catinga forests characteristic of the semi-arid portions of the interior of Bahia. Near the Rio São Francisco there are some wide alluvial belts, but for the most part, although the surface is flat, the rocks are either granites, or gneisses, or they are limestones of recent freshwater origin, spread in a thin layer over an old planed down granite surface. These limestones are characteristic of the high-flood plains of the Rio S. Francisco, and will be described in a later paper.

The road from Joazeiro to the Serra do Mulato crosses into Salitre at fazenda Gamelleira, forty kilometers from Joazeiro and thirty-eight from where the Salitre enters Rio S. Francisco. The rocks exposed at that place are slippery green talcose slates standing nearly on end and traversed by many small quartz veins. On the southwest side of the river these slates strike S. 50° W. magnetic; at the fazenda Gamelleira residence the strike of the slates is S. 15° W. magnetic.

About thirty meters west of Rio Salitre at Gamelleira crossing a dike of dark greenish diabase traverses the slates.* This

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*** Dr. A. F. Rogers has examined specimens of this rock and kindly furnishes the following note in regard to it:**

The specimen is a dark-colored basic igneous rock and is referred to a diabase. As seen with a hand lens, it consists of two principal constituents,

dike is about 12 meters wide, but is not traceable any farther toward the north; it extends southwestward up Rio Salitre, however, following the strike of the slates, and widening somewhat in that direction. It was followed only for a distance of 200 meters or so. The following section shows the general geology as it appears along the road from Joazeiro to the fazenda Gamelleira.

FIG. 2.

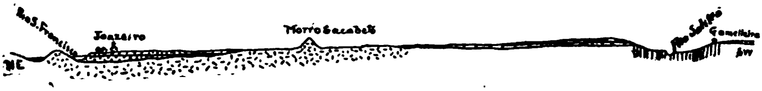

FIG. 2. Generalized northeast-southwest section, showing the geology between Joazeiro and Rio Salitre.

To the right or north of the road, as the Serra do Mulato is approached, is a long, low and narrow range of hills called the Serra da Batateira. With considerable difficulty one can break and cut his way through the catinga forest and cactus to this range. At its southern end it rises only about twenty-five or thirty meters above the level of the plain. It is composed of very compact quartzites, the beds are clearly defined and stand nearly on end, the dip being 70° east, magnetic. This ridge extends north and northeast some twenty kilometers nearly to the Rio São Francisco. The flat plain about the base of this ridge is strewn with fragments of this same quartzite. About three kilometers to the south is another sharp hill which was not visited, but which appears from a distance to be of the same geologic structure as the Serra da Batateira. In the flat ground between the two ridges the soil has the peculiar snuff-color characteristic of the limestone soils hereabout, and the occasional loose lumps of limestone show that there is here a thin sheet of recent lime-rock, though it is mostly decomposed. Two kilometers west of the Serra da Batateira gneissoid granites are exposed on the plain, and similar rocks crop out along the trail to the ranch house of the fazenda Itumirim, which is about two kilometers north of the base of the Serra do Mulato.

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elongate light-colored crystals set in a black matrix. The texture is that of a coarse-grained diabase.

The principal minerals seen in the thin sections are: (1) hornblende, prismatic crystals with the characteristic pleochroism; (2) ilmenite altered to leucoxene; (3) epidote, light-colored irregular mineral with high relief; (4) zoisite, recognized by high relief and Berlin blue interference colors; (5) secondary quartz in clear grains. Besides these there are elongate much altered crystals which probably represent feldspars. The rock is an altered diabase, with scarcely any of the original minerals present.

A. F. ROGERS.

Stanford University, Feb. 9, 1909.

Although the fazenda Itumirim is some thirty kilometers south of the Rio São Francisco, the plain that borders the river extends to the south of the ranch house and ends abruptly against the base of the Serra do Mulato. Hereabout this plain is not alluvial, but is a flat floor of granites and old crystalline rocks cut down apparently by the ancient river itself. So flat is this plain that it is but rarely that a more resisting point rises three or four meters above its general level. In the vicinity of the fazenda Itumirim the rocks exposed in place are all banded or sheeted granitoid gneisses. The sheeting dips eastward at an angle of 80°, and the texture of the rocks is remarkably even. Over the surface of these rocks are strewn loose fragments of quartz, most of them sub-angular and somewhat worn by water.

FIG. 3.

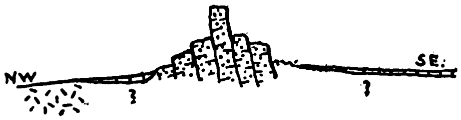


FIG. 3. Section across the south end of Serra da Batateira, showing the nearly vertical quartzites.

Within two hundred meters of the base of the Serra is a boss-like outcrop of compact and very hard granite that rises two or three meters above the general level of the plain. It has exfoliated somewhat from exposure to the sun, but here and there over this boss, and especially about its base, are well-preserved remnants of waterworn surfaces. These worn surfaces are not pits or depressions such as are often made by aborigines in grinding food, but they are uneven, rounded, smoothed, and polished like the worn hard rock in the bed of the stream. As these bosses stand in the open plain and out of reach of any possible local wearing, it seems clear that they were worn by the São Francisco river itself at a time when its flood waters covered a much larger area than they do at present. The altitude of this plain at the base of the Serra, as determined by aneroid readings carried from the railway station at Joazeiro, is about 400 meters above sea level, and 28 meters above the station at Joazeiro.

Starting up the side of the Serra do Mulato on its north face, the first rocks found in place are some dark-colored crystalline schists. Examined under the microscope, these rocks are found to be composed chiefly of hornblende and epidote.

From this point up to the base of the bare cliffs that encircle the north escarpment of the mountain there are no trails, and the slopes are covered with a dense growth of catinga forest and cactus difficult to penetrate even under the most favorable circumstances.

On the mountain slope at an altitude of 450 meters the ground in certain localities is strewn with enormous quantities of large, loose, somewhat waterworn bowlders. These bowlders are mostly of the sandstones and quartzites that form the resisting ledge that caps the summit of the mountain. This belt of bowlders suggests the possibility of an ancient water level. It is here mentioned because at about the same altitude similar bowlder zones have been found at other places in the valley of the Rio São Francisco. At 580 meters is an exposure of soapstone or talc that forms a belt running along the northeastern side of the Serra do Mulato. At 640 meters fragments of dark hornblende schists are strewn over the surface of the mountain slope. At 700 meters the rocks are compact black eruptives resembling diabase. At 740 meters is the base of the vertical escarpment made by the massive quartzites that form the flat top of the mountain.

Fig. 4.

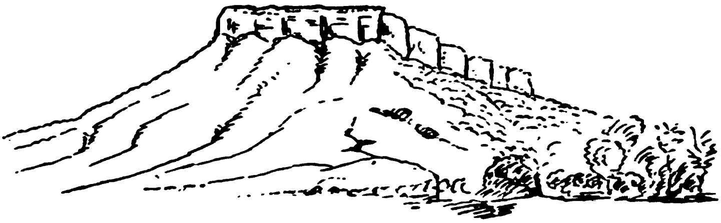


Fig. 4. Serra do Mulato seen from fazenda Itumerim. The flat summit is of Tombador quartzites; the slopes and plain in the foreground are of crystalline rocks.

In order to pass the wall made by these quartzites and reach the summit of the mountain it was necessary to skirt along the east base for about two kilometers. Nowhere in this distance was the actual contact between the quartzites and the underlying crystalline rocks seen; it is evident therefore that the contact is lower down the mountain slope and is concealed by talus and soil.

The necessity for skirting the base of the bluffs afforded an excellent opportunity for examining the rocks and looking for fossils. The quartzites are mostly fine-grained, and nearly all of them show false bedding with remarkable clearness. In the talus slopes below were seen abundant angular blocks of conglomerate, which must necessarily have come from some part of this series of sediments. The bluff, however, is more than a hundred meters high, and, being inaccessible, could only be ascended at one point on the east side, and no conglomerates were seen at that place. Careful search was made for fossils, but the materials are most unpromising. At a few places there were found some dark angular fragments that suggested plant remains, but if they are such, they are quite unrecognizable. One thin (20 centimeters) bed was found which from its resemblance to a stratum of mud seemed to hold forth some promise. It was so altered, however, that it was quite schistose.

The age of these sedimentary beds cannot therefore be determined at present either from fossils found in them or by reference to any rocks immediately above or below them.

The altitude of the top of the mountain above sea-level is 865 meters; the thickness of the horizontal quartzite beds that cap the summit is something more than 125 meters; the height of the mountain top above the old flood plain at its base is 465 meters.

FIG. 5.

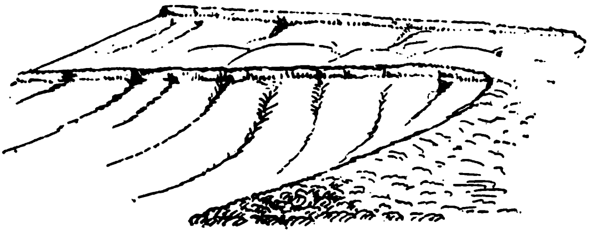


FIG. 5. Serra do Boqueirão and Serra da Cruz seen from the top of Serra do Mulato. The flat summits are Tombador quartzites.

From the top of the Serra one has a good view of the two mountains that lie to the east. These are the Serra do Boqueirão lying next to the Serra do Mulato, and the Serra da Cruz still further to the east. Seen from here, the geologic structure of these two mountains and their relations to the Serra do Mulato are plain and simple. The horizontal quartzites that cap the Serra do Mulato can be followed with the eye along their outcrop to these neighboring mountains, which are capped by this same series of sediments. The Serra do Boqueirão is somewhat lower than the Serra do Mulato, of which it is simply a spur. The valley that separates these two points is a low breached anticline. The Serra do Boqueirão is a synclinal ridge, while between this and the Serra da Cruz is another anticlinal valley. The folds forming these valleys and ridges are gently and clearly defined, and all three of these mountains are simply the conspicuous spurs of an elevated region lying to the south. From one position on the plain to the northeast as one looks back toward this group of mountains their structural relations to each other can be readily seen. The accompanying profile was sketched from that point.

A later trip made across the region south and west of this group of mountains, and trips made by assistants along the Rio São Francisco, show that the quartzite beds that cap the Serra do Mulato in a similar way form the flat summits of the Serra do Encaibro just east of Sentosé, and of the Serra do Tombador south of Remanso. In other words, the great group of mountains sometimes spoken of as the Serras do São Francisco have these quartzites at the base of a great sedimentary series that is developed in the diamond regions of the interior of Bahia.

FIG. 6.

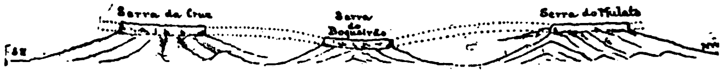


FIG. 6. Diagrammatic section showing the structural relations of the Serra da Cruz, Serra do Boqueirão, and Serra do Mulato. The crests are of Tombador quartzites; the slopes and plain are of old crystalline rocks.

It remains to call attention to the relations of the Serra da Batateira to the Serra do Mulato and the other mountains in the latter cluster. That particular range is mentioned here because it represents a type of geologic structure common at many places in the state of Bahia. It seems clear that the Serra da Batateira belongs to a series of very old sediments that have been closely folded and faulted. Whether these sediments are older or newer than the crystalline rocks next to them is not certainly known at present, but the writer is of the opinion that most of the granites are older. The structure, in so far as it was made out in two trips across the region, is shown by the accompanying section. (See fig. 3.

In the region south of Joazeiro and east and south of Villa Nova are similar narrow, sharp, quartzite ridges with their beds standing nearly on end. These ridges generally have the granites and gneisses on both sides of them. This leads one to conclude that they are the last remnants of a very old series of sediments let down into the older granites by faults, perhaps as suggested in the accompanying section. (Fig. 7.)

The limestones in the section are recent, possibly Tertiary, fresh-water deposits surrounding the ridge, and have been cut out, or were never deposited, along the stream courses. The evidence of the age of these limestones is conclusive, but cannot be presented here.

Conclusions.—The excursion to the Serra do Mulato made it possible to determine the following facts regarding the geology of the region south and southwest of Joazeiro:

FIG. 7.

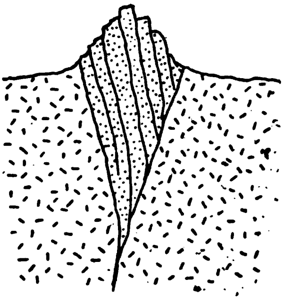


FIG. 7. Section showing the theoretical relations of the ridges of vertical quartzites.

1. The low flat region forming most of the high flood-plain of the Rio S. Francisco is made up of two series of rocks:—I, an older series of crystalline schists, other metamorphics, and eruptives; and II, a series of highly metamorphosed quartzites and schists or shales.

2. Faults have let the old quartzites down into the crystalline rocks here and there, and the upturned edges of these beds form the white walled mountains and hills that are scattered far and wide over the old base-leveled plain. The Serra da Batateira belongs to this type. (See fig. 3.)

3. The flat-topped mountains so common to the west and southwest of Joazeiro, such as the Serra da Cruz, Serra do Mulato, Serra do Encaibro, and the Serra do Tombador south of Remanso, are formed by approximately horizontal beds of Paleozoic quartzites which rest directly upon the old crystalline series.

4. This series of quartzites was later traced up the Rio São Francisco, southward across Rio Salitre at the falls, and farther south to the region about Jacobina. It usually forms a bold escarpment.

5. On account of this series of quartzites forming the Tombador range west of the city of Jacobina, it has been named the Tombador series.

6. No recognizable fossils have thus far been found in these Tombador quartzites. They are called Paleozoic on account of stratigraphic relations found in the region to the southwest.

7. Limestones cover the higher portions of the elevated flood-plain of the Rio São Francisco.

8. These limestones are of fresh-water origin and of Tertiary and later age.

Stanford University, California.

ART. XXVI.—*An Australian Meteorite;* by L. LAYBOURNE SMITH.

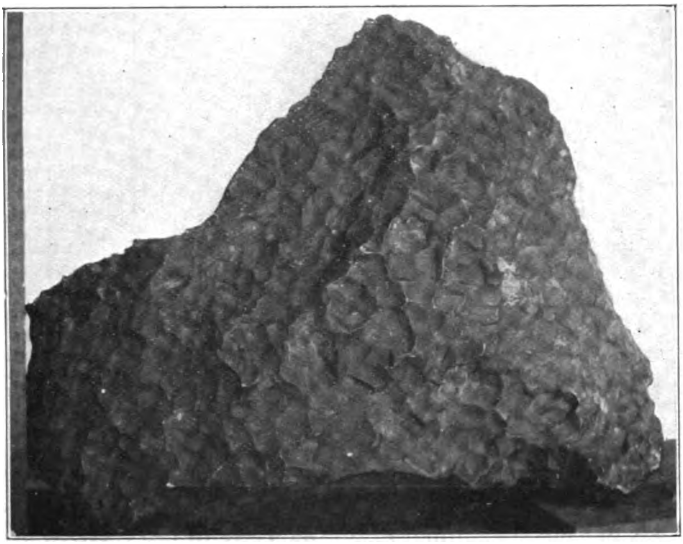
A METEORITE of particular interest has lately been discovered at Murnpeowie in South Australia. It has been acquired by the Council of the School of Mines at Adelaide for exhibition in the mineral and petrological museum of that institution. The new meteorite is a siderite, and is the fourth find of that class to be credited to the central Australian state. The list now comprises the "Yardea," 7¼ lbs.; the "Rhine Villa," 7½ lbs. (described in the S. A. School of Mines Report 1900); the "Arltunga," 40 lbs. (not yet described); and the "Murnpeowie," 2520 lbs.

The discovery was made by some boundary fence repairers working on the Beltana Pastoral Company's Murnpeowie run, at a spot 29° 35′ latitude and 139° 54′ longitude, being about 16 miles N.E. by E. of Mt. Hopeless. The country at the place is flat and devoid of stones. The men thought the meteorite to be an isolated rock, and used to stand on it when scanning the plain in search of their donkeys. One day one of the men struck the stone with a hammer, and was astonished at the bell-like sound which it emitted. With much difficulty they were enabled with chisel and crow-bar to fracture off a small piece, which they forwarded to the School of Mines at Adelaide, which institution has a department where assays of minerals found on the Crown Lands of the State may be made and results supplied to applicants free of charge. On being informed that they had discovered a meteorite, they wrote to me offering to sell their find, with the result mentioned above.

The work of transporting the meteorite to Farina, the nearest point to the railway, was undertaken by two men with a wagon drawn by 26 donkeys. The journey to and from the site of the find, a distance of 278 miles, occupied 27 days. The ground was dug away and the wagon lowered until its floor was level with the surface, and the meteorite then turned over —the donkeys pulling on chains. A careful search was made for further pieces but without success. In the vicinity of the find was a hole which I am of opinion was made by the falling meteorite. This hole was roughly elliptical in shape, with its major axis almost due east and west. It measured 16 ft. 6 in. in length, its greatest width 12 ft., and it was 4 ft. deep. The meteorite was lying a distance of 70 yards from the eastern end of the hole and in the direction of the longer axis. The earth had been thrown out into two ridges extending radially for 15 ft. on either side of the hole. Between the meteorite and the hole were two smaller indentations. It appears, therefore, that the meteorite travelled from a little north of west, and, having torn up the ground on striking, ricochetted, and came to rest practically on the surface of the ground. It was lying breast uppermost with the heavier end nearest the hole and raised some inches.

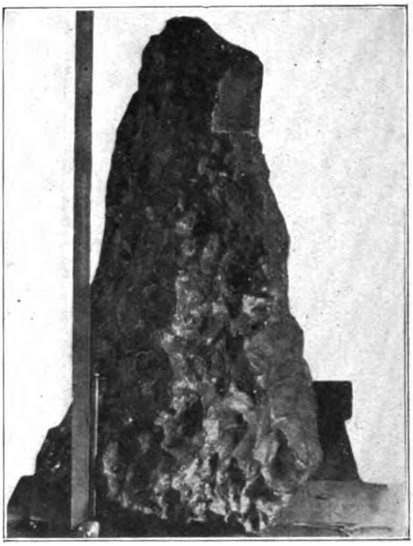
From a preliminary examination of the méteorite, I am of opinion that it is an "oriented meteorite," the breast being shown in the photograph (fig. 1). The greatest height is 35 inches, width 47 inches, thickness at the right hand corner 19 inches, left hand corner 9 inches. It tapers off toward the top, where the thickness is 8 inches. The front shows some convexity, whilst the greater part of the back is distinctly concave. The piezoglyphic depressions are particularly well developed. On the front they are comparatively small, the cusped groups measuring 3 to 5 inches in diameter, and some half an inch in depth. Many of the markings are deeper in proportion, and resemble the imprints of an animal's paw in some soft material. On the back of the meteorite the grouped depressions measure from 5 to 10 inches across. The ridge outlining the meteorite is sharp in parts, and shows distinctly the effects of fusion from front to back. Drift markings or striations are only noticeable on the front, and occur as more or less horizontal lines—more pronounced on the right side, where they turn in a downward

Fig. 1.



direction. The meteorite is covered with a varnish-like coating, reddish brown in color, and on the back where it has been lying on the ground there is also a rougher black oxide incrustation. There are several distinct cracks, caused, no doubt, by sudden heating on entering the atmosphere. The metal is tough, but may be cut with a hack-saw. An etched face indicates a fine brecciated structure, the particles varying in size, but not exceeding 5^{cm} in diameter in the sections so far polished. The grains are probably kamacite, and are surrounded by fine fissures filled with troilite. They are characterized by brilliant, depressed Neumann lines. The chemical composition has not yet been determined, but is now being undertaken and a careful micro-metallographical examination will also be made. I am making enquiries with a view to finding the probable date of the fall. It appears hardly likely that this took place previous to the erection of the vermin-proof fencing some five years ago. Australian bushmen are very observant, and this isolated stone would not have been overlooked in a position less than half a mile from where the fencers were working. The holes also would fill with sand in a few years. It is probable, therefore, that the Murnpeowie meteorite is a recent arrival.

Fig. 2.



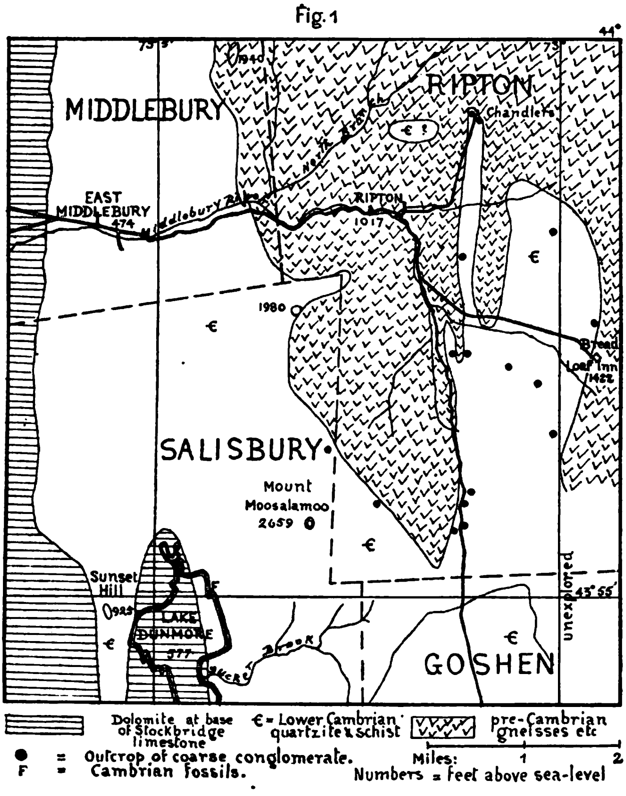
S. A. School of Mines Museum, March 4, 1910.

Art. XXVII.—*The Cambrian Conglomerate of Ripton in Vermont;* by T. Nelson Dale.[*]

Hitchcock and Hager[†] represented a strip of "talcose conglomerate" as beginning a little south of the village of Ripton in Addison Co. and widening northwards in the township of Lincoln, attaining its greatest width, 6 1/2 miles, in Chittenden Co., and extending to the Canada line.

In Ripton it appears as bordered on the east by the granites and gneisses which form the axis of the Green Mountain range and on the west by the quartzite and schist which underlie the marble and dolomite of the Vermont Valley.

Fig. 1



In 1903 the writer, in working on the areal geology of the Brandon sheet for the Fort Ticonderoga Folio of the U. S.

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[*] Published by permission of the Director of the U. S. Geol. Survey.

[†] Report on the Geology of Vermont, 1861, vol. II, map, pl. I. See also vol. I, p. 388, 2d–4th paragraphs and page 346, 2d paragraph.

Geol. Survey, came upon a coarse conglomerate of this formation, continued his study of it in 1904, and revisited some of its outcrops with Mr. Arthur Keith in 1908. A preliminary geologic map of the northwest corner of the Brandon sheet with a half mile strip east of it is shown in fig. 1. The trend of the frontal part of the Green Mountain range is indicated by the altitudes taken from the contour map. The pre-Cambrian gneisses are not differentiated nor are the members of the Cambrian series. Dikes of diabase altered to amphibolite cut the gneisses but are not shown on the map.

The age determination of the Cambrian was confirmed by the writer's discovery in 1903 in an outjutting mass of quartzite on the east shore of Lake Dunmore (point marked F on map) of pteropods determined by Dr. C. D. Walcott as *Hyolithes* of type *communis* and of spines of *Olenellus*. In 1890 Dr. Walcott* mentioned his finding an Ostracod with a marked resemblance to *Nothozoe* in a quartzite bowlder on Sunset Hill on the east side of Lake Dunmore, and his having previously found the same fossil in situ in the quartzite east of Bennington associated with *Olenellus* and *Hyolithes impar*.

The quartzite of the west flank of the Green Mountain range appears to be interbedded with schist and this conglomerate forms the base of the formation. The conglomerate was observed at the points indicated on the map, but its most interesting outcrops are that about 1/2 mile E.N.E. of the top of Mount Moosalamoo and also that near the Chandler house, 1 1/4 mile N.E. of Ripton village. The cement of the conglomerate is highly metamorphic, generally a muscovite-quartz schist with more or less magnetite. More than half of the pebbles are blue quartz and the rest are gneiss. At the locality near Mount Moosalamoo the conglomerate lies close to the pre-Cambrian gneiss and has a N. 15° W. strike, a 50° to 80° E. dip, and a minimum thickness of 58 ft. Most of the pebbles range from 3 to 6 inches in diameter but the largest ones measure 10 × 8 in., 14 × 12 × 6 in., 20 × 9 1/2 in., and 23 × 16 × 7 in. This last is shown in fig. 2. At Chandler's the conglomerate strikes N. 67° E. and dips 90°. Here a pebble of blue quartz measures 76 × 57 × 30 in. and over. Its major axis strikes N. 30° E. It might easily be mistaken for a vein. See fig. 3.

Bowlders of the conglomerate have been carried southward by the ice sheet into the towns of Goshen and Salisbury. One near the Dutton brook schoolhouse, 4 1/4 miles south of the Ripton-Goshen line, contains pebbles to 8 × 6 in. Another bowlder, 20 × 10 ft., in Sucker brook about 1 1/4 mile S. 10° W. from the top of Mount Moosalamoo, consists of micaceous quartzite containing three beds of conglomerate to a foot thick, the larger pebbles of which measure 12 to 15 inches across. No glacial striæ were made out on any of the pebbles.

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* U. S. Geol. Surv., Tenth Ann. Rept., Part I, p. 268.

A number of pebbles from these various localities were studied microscopically and fall into these groups: Blue quartz; biotite granite (medium-coarse); biotite-muscovite granite (fine); biotite granite or biotitic quartz monzonite (fine); muscovite granite or muscovitic quartz monzonite (fine); muscovite granite-gneiss (fine); aplite-gneiss, pyritiferous (fine); quartzite, two small pebbles from locality near Mount Moosalamoo.* Both quartzite and igneous rock pebbles contain rhombs and irregular plates of a ferruginous carbonate passing into limonite, which are also characteristic of the pre-Cambrian gneisses about Ripton.

FIG. 2.

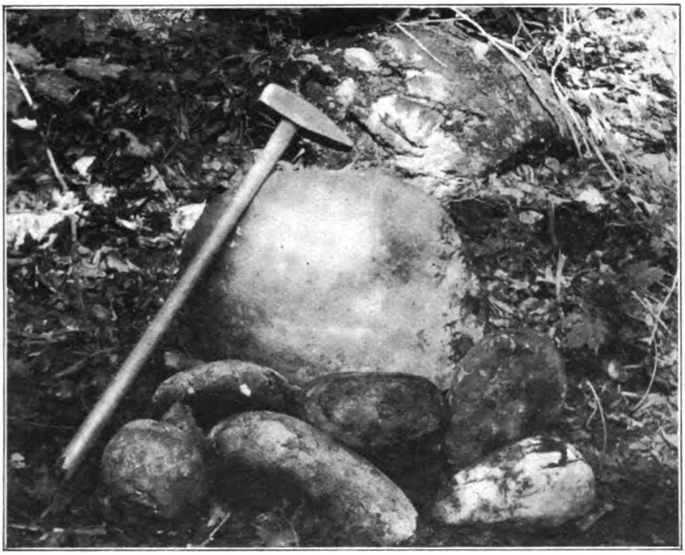

FIG. 2. Beach pebbles of pre-Cambrian gneiss and blue quartz weathered out of Lower Cambrian metamorphosed conglomerate on the east spur of Mount Moosalamoo, 1/2 mile E.N.E. of top, in Ripton, Vt. Sledge 30 inches long. Largest pebble 23 x 16 x 7 inches (gneiss).

As to the origin of these pebbles: With the exception of the quartzite and the aplite-gneiss all these rocks have already been found in situ in the pre-Cambrian area shown in fig. 1. The blue quartz is identical with that of a mass cut by the

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* Determination of aplite by E. S. Larsen, Jr., of U. S. Geol. Survey, that of quartzite confirmed by him.

Middlebury River 1/2 mile west of Ripton village, which, judging from its relation to other outcrops on the hillside south, probably measures about 500 ft. from east to west and 1500 ft. from north to south, tapering out at the north. Some parts of this blue quartz are schistose, but a thin section of that shows no feldspar but a matrix of sericite carrying large particles of quartz containing a few biotite scales. If the sericite is altered feldspar, then we have to do with a very acidic granite-gneiss, but most of the blue quartz rock is probably of pegmatitic origin. Fine-grained quartz monzonite crops out at points 1 1/4 miles west and 1 3/4 miles N.E. of Ripton village.

FIG. 3.

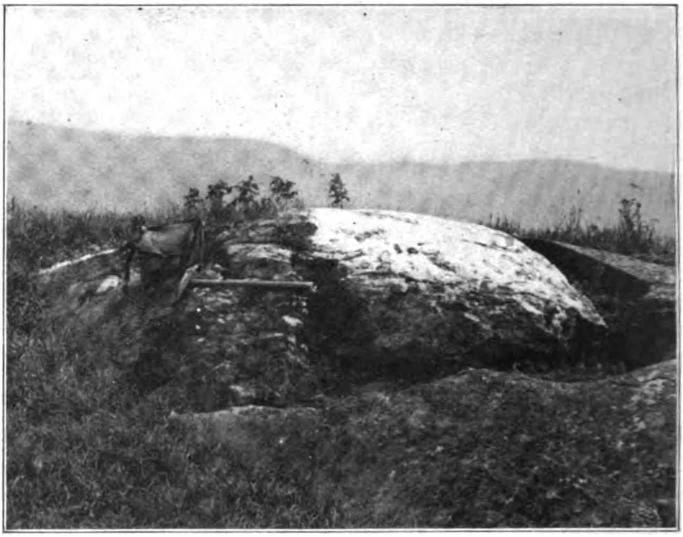

FIG. 3. Beach pebble of blue quartz of pre-Cambrian origin in schist and conglomerate of Lower Cambrian age near Chandler house in Ripton, Vt. Size 76 x 57 x 30 inches. Sledge and bag rest on conglomerate. In distance central range of Green Mountains.

Conclusion: The generally rounded or discoid form and the unstriated surfaces of these pebbles from the Cambrian conglomerate point to their having been formed on a beach, and their magnitude points to their local origin, which is corroborated by the occurrence of identical gneisses, quartz monzonite and blue quartz in the underlying or adjacent pre-Cambrian. The quartzite pebbles show the existence of Algonkian sedimentary rocks on the Green Mountain range. These large beach pebbles thus take us back to the time of the Cambrian sea as it advanced over the very slowly subsiding pre-Cambrian land-mass of central Vermont.

Pittsfield, Mass., June 21, 1910.

ART. XXVIII.—*Some Tests upon the Synthetic Sapphires of Verneuil*; by ALFRED J. MOSES.

VERNEUIL describes briefly* synthetic sapphires of "beautiful color" made in his oxyhydrogen furnace by adding to the alumina "1½ per cent. of magnetic oxide of iron and ½ per cent of titanic oxide." The resulting ovoids or cone-shaped masses are said on authority of Wyrouboff to be "unique crystals, uniaxial, negative, weakly doubly refracting and with, consequently, the optical properties of the natural sapphire."

An examination of material sent by L. Heller & Son consisting of one dozen of the cut stones and one of the uncut cone-shaped masses yielded some exact figures which are here stated.

Three analyses were made by my assistant, Dr. M. A. Lamme. No. 1—Transparent fragments of the uncut cone, not including either the blackish scoria-like material at the apex or the thin brownish layer at the base. No. 2—Two small cut stones, one deep blue, one pale blue in color. No. 3—One deep blue cut stone.

	1 Weight 0·4070 gm.	2 Weight 0·3990 gm.	3 Weight 0·2966 gm.
Al_2O_3	99·84	99·85	99·83
Fe_2O_3	trace	trace	trace
TiO_2	0·11	0·12	0·13
SiO_2	none	none	none
	99·95	99·97	99·96

The material was crushed in a diamond (steel) mortar, through a 100-mesh screen and all particles of steel removed by the repeated use of a strong magnet. It was then fused with $KHSO_4$. The alumina obtained was re-fused for a colorimetric determination of TiO_2.

There are few recorded analyses of true sapphire and I believe none showing either chromium or titanium. The coloring matter suggested by these analyses is iron. For instance:

	India†	Ceylon‡	Ceylon‡
Al_2O_3	97·51	99·33	99·26
Fe_2O_3	1·95	0·92	0·97
SiO	0·80	----	----

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* Comptes Rendus, Jan. 17, 1910.

† J. Lawrence Smith, this Journal (2). xi, 54, 1851.

‡ Karl Pfeil, Centralblatt f. Min., 1902, p. 145.

The following physical and crystallographic characters were determined by me:

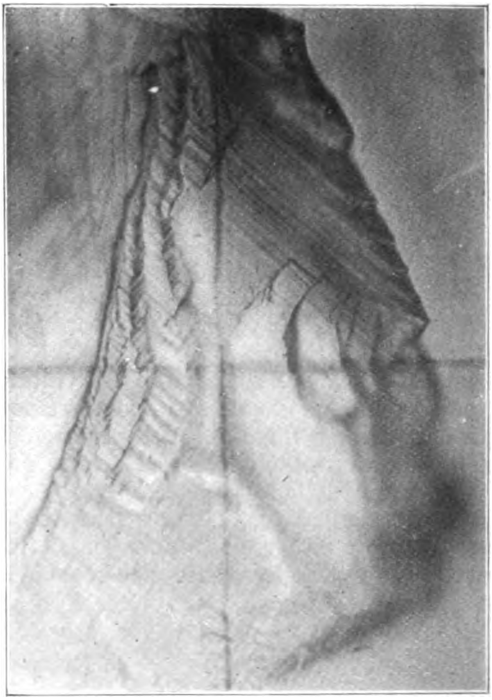
Hardness 9, that is less than that of carborundum, greater than that of chrysoberyl and not noticeably different from that of the natural sapphire. In grinding it was very little affected by emery.

Specific gravity as determined upon one polished fragment of the cone and upon two of the cut stones.

Cone	3·988
Cut stone	4·01
Cut stone	3·977

Natural sapphire is stated by Bauer (Edelsteinkunde, p. 319) to have the specific gravity of 4·08.

Fig. 1.



Parting. Although the finely crushed fragments of the cone examined under the microscope showed in general only irregular to conchoidal fracture, some of the particles showed a development of sets of parallel-plane separations at angles near 90°. These are shown in the accompanying cut with a magnification of 225 diameters and strongly suggest the planes of separation parallel $10\bar{1}1$ described by Bauer[*] in true sapphire for which the angle is 93° 59′.

Double Refraction and Indices of Refraction.—Sections were made from the uncut cone and polished and the "tables" of four of the larger cut stones were used directly. For each surface the direction yielding the largest and smallest indices was determined by trial. The instrument used was the latest form Abbé crystal refractometer, the liquid a solution of sulphur in methylene iodide with $n = 1{\cdot}784$, and the temperature 20° C. The sodium flame was used.

	ω	ϵ
Surface parallel cone axis	1·7678	1·7600
Surface perpendicular cone axis	1·7684	1·7600
Cut stone table	1·7676	1·7580
" " "	1·7678	1·7598
" " "	1·7683	1·7592
" " "	1·7684	1·7598

We may, therefore, take as the most probable values for synthetic sapphire the averages

$$\omega = 1{\cdot}7680 \qquad \epsilon = 1{\cdot}7594 \text{ and } \omega - \epsilon = {\cdot}0086$$

For natural sapphires the following results with sodium light are recorded:

	ω	ϵ	$\omega-\epsilon$
Sapphire from Ceylon (Brauns)	1·7693	1·7610	·0083
Sapphire from Burmah (Melczer)	1·7692	1·7609	·0383

Pleochroism.—Very noticeable with the deeper blue stones, ω indigo blue as in true sapphire, ϵ pale blue but without the greenish and yellowish tints often noticed in the true sapphires.

Interference Figure and Optic Axis.—In finely crushed material a negative apparently uniaxial interference figure was obtained on several different grains.

Two surfaces were then polished on the conical mass approximately at right angles to each other, the direction in each determined which yielded the smallest extraordinary index and a section about 2^{mm} thick was made as nearly as possible parallel to the plane of these two directions, such a section being approximately perpendicular to the optic axis of the cone. The section yielded a distinct, many ringed, but eccentric interference figure optically negative. A thinner section ground until the figure was nearly central showed anomalies, being apparently true uniaxial in one portion but definitely biaxial in others with the orientation of the axial plane varying. Similar optical behavior is recorded for some crystals of true sapphire. The optic axis was not coincident with the cone axis but was at about 40° to it.

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[*] Zeitschr. d. Geol. Ges., xxvi, 192, 1874.

While, strictly speaking, the crystalline system is not determined, the recorded tests show that the cone-shaped mass is an anhedral crystal with all determinable characters closely resembling those of natural sapphire.

ART. XXIX.—*A Cretaceous Lycopodium;* by EDWARD W. BERRY.*

FOSSIL remains of club mosses are exceedingly rare especially in beds of Mesozoic age and such as have been described have nearly all been based upon fragments of foliage not at all conclusive in character, since such fragments may, and usually are, found to be referable to some conifer when additional or more complete material subsequently becomes available.

A number of forms have been described from the Paleozoic which show some of the fructification characters and which ally these ancient forms with the modern Lycopodiums. These are usually referred to the genus Lycopodites of Brongniart. In post-Paleozoic rocks, however, not a single specimen showing the character of the fructification, and consequently referable with certainty to Lycopodium, has been discovered, at least to the writer's knowledge.

Hence the following species is of considerable interest. The remains are in the form of crushed impressions preserved in a clay lens in the Upper Cretaceous sands near Middendorf, in Chesterfield County, South Carolina. These beds are of early Upper Cretaceous age and contain an abundant flora which stamp them as about the same age as the Magothy formation of the more northern Atlantic Coastal Plain, or according to European standards, probably corresponding with the Turonian. These lycopodiaceous remains consist of fruiting spikes or fragments of spikes to the number of 17 specimens, and while they leave much to be desired in the way of preservation, enough is discernable to stamp them as closely allied to the existing species of Lycopodium. These spikes are not badly crushed as is shown by fig. 1, which is a photograph of one of the largest ones found. They are made up of a central stout axis, bearing numerous rows of close set but poorly imbricated bracts, each bract apparently subtending a large spheroidal sporangium.

The spikes show considerable differences in size, the shorter and smaller ones being less crowded and somewhat lax in appearance. The largest one collected is 5^{cm} in length by 5^{mm} in diameter and is nearly complete. The average dimensions are, however, somewhat less than this. The bracts have a narrow acute apex, a broad laminar somewhat thickened portion, with a truncate or slightly cordate or retuse base and a short peduncle. The margin is entire. Fig. 3 is a drawing of one of these scales as it occurs slightly twisted and flattened out in the clays. Fig. 4 is a diagrammatical drawing of a bract showing the position of the sporangium. Figs. 5 and 6 are diagrammatical sketches of the two modes of appearance of the bracts and their sporangia in lateral view, the bract being apparently curved upward in fig. 5 while in fig. 6 it is thickened thoughout the laminar portion and turns sharply upward immediately beyond the sporangium. The latter is believed to be the normal form, the other being probably due to the method of preservation. The method of attachment of the sporangia cannot be made out; they are in the axils of the bracts, but whether attached to the axis or to the dorsal face of the bract as the drawings would indicate cannot be determined. It is probable that the arrangement is the same as in the modern species, but there is a possibility that they were attached to the bract and this possibility is worth mentioning because of the wide interval between the sporangium and the axis in some of the Paleozoic Lycopodiales.

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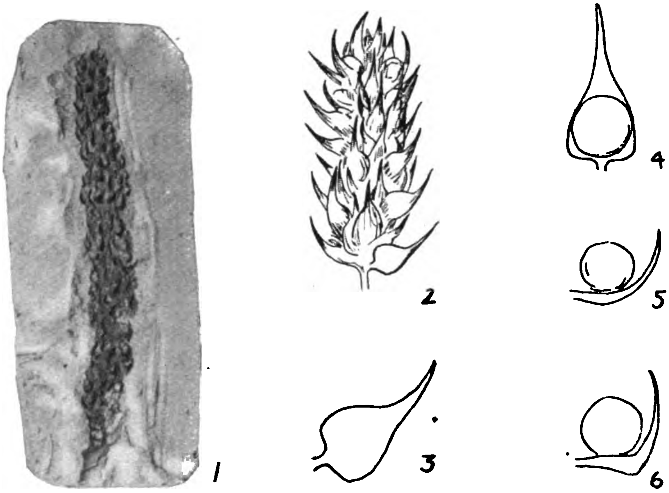

FIG. 1.—*Lycopodium cretaceum* sp. nov.

1—Photograph of a large specimen, natural size.
2—Drawing of small specimen, × 5.
3—A single bract, × 10.
4, 5, 6—Somewhat diagrammatical drawings of bracts and their sporangia, × 10.

There is nothing to indicate that these sporangia were not reniform in shape as in the modern Lycopodium instead of spheroidal as they appear in the fossils; the character of the base of the bracts would tend to show that they were reniform.

No remains of foliage which can be correlated with these fruiting spikes has been found in association with them or in beds of homotaxial age elsewhere in South Carolina, so that the vegetative character of the species remains unknown. The species may be called *Lycopodium cretaceum.*

Johns Hopkins University,
Baltimore, Md.

ART. XXX.—*New Units in Aero-physics*; by ALEXANDER McADIE.

Pressure.

SINCE the time of Torricelli and Pascal, measures of atmospheric pressure have been in linear units; i. e., the height of a column of water or mercury in vacuo. The barometer, in English-speaking countries, is read in inches and decimal parts thereof; and in countries where the metric system prevails, in centimeters or millimeters. For example, a standard atmosphere is generally defined as the pressure of a vertical column of pure mercury whose height is 29·92 inches or 760 millimeters, at the temperature of melting ice, in latitude 45°, under normal gravity and at sea level. Evidently then, if one wishes to know the ratio of certain changes in atmospheric pressure occurring from day to day and from hour to hour, variations which are of prime importance to the meteorologist, he must refer the change to some normal or assumed standard height. For example, a fall or a rise of ·75 of an inch would be $\frac{\cdot 75}{29\cdot 92}$ or, if metric values are used, $\frac{19}{760}$ mm. Again, in expressing lines of equal pressure, as on the daily weather maps, we draw for differences of one-tenth of an inch; or, if the 2^{mm} gradient is used, ·078 of an inch. The method of reduction is cumbersome; and it is doubtful if the average reader of the synoptic charts obtains any clear conception of the actual meaning of pressure variations. The entire process of representing pressure conditions would be much simplified if variations could be given in percentages or permillages of a standard atmosphere. Such an arrangement was suggested by the writer in a paper published in the Monthly Weather Review in August, 1908. Dr. W. Köppen* of the Deutsche Seewarte, Hamburg, in March, 1909, modified the proposal, suggesting instead of the sea-level pressure, the new base, the pressure represented by the value one million dynes. In other words, instead of using the pressure indicated by 760^{mm} (29·92 inches), which in force units would be 1,013,303 dynes (obtained by multiplying 1033·291 grams per square centimeter by normal acceleration of gravity 980·65), use a megadyne, corresponding to a pressure of $750\cdot 1^{\text{mm}}$ (29·532 inches). This quantity is called a *small* atmosphere (with Bjerknes and Sandström) or a *Bar*.

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* See also Köppen's Memoir before the Aerological Congress at Monaco, April, 1909.

Abbreviations corresponding to others in the metric system would be b, db, cb, mb.

The new pressure base is found at a height of 106^{mm} (348 feet) above sea level, a level that is very convenient for many reasons, which cannot be gone into here.

The following short table may be found helpful in connection with the new system :

To convert Pressure into Megadynes (*C. G. S. Units*).

23 inches	=	·779 mgd.	·1 inch	=	·0033	·01	=	0
24 "	=	·813 "	·2 "	=	·007	·02	=	·001
25 "	=	·847 "	·3 "	=	·010	·03		
26 "	=	·881 "	·4 "	=	·014	·04		
27 "	=	·914 "	·5 "	=	·017	·05	=	·002
28 "	=	·948 "	·6 "	=	·020	·06		
29 "	=	·982 "	·7 "	=	·023	·07		
30 "	=	1·016 "	·8 "	=	·026	·08	=	·003
31 "	=	1·050 "	·9 "	=	·030	·09		

Thus at Denver, elevation 5,291 feet, the mean barometer reading is 24·708 inches. In the new unit this would be ·834 mgd. or 834,000 dynes. At New York, elevation 314 feet, the mean pressure is 29·695 inches, or 1,004,000 dynes. Between the two stations, then, one readily perceives there is a gradient of 170,000 dynes, or in round numbers 17 per cent.

It will also be noted that the new system permits the widest possible range and is entirely suitable for the needs of the investigator at high levels, such for example as in the work done during the past two years with ballon sondes, free balloons and kites. Dr. W. N. Shaw, Director of the Meteorological Office, in a recent paper* on the "Investigations of the Upper Air" uses the new unit (see page 280) and rightly says: "The reason for adopting this unit is that in the examination of the results of the upper air, the actual number of inches or millimeters in the pressure at any level is of little importance, compared with the fraction of the atmosphere that is above or below the level."

It may not be generally known that recent observations have brought out the fact that our atmosphere is practically in two sections, a lower or troposphere and an upper or stratosphere. Below 11 kilometers the atmosphere is in a disturbed condition, convectional currents are well marked, and cyclonic circulations prevail. The decrease of temperature is nearly adiabatic, although at times there are strongly marked inversions. In the stratosphere there is a slight rise in temperature with isothermal conditions up to 27 kilometers. Tiesserenc de Bort* has shown that "the stratosphere is lowest in the cyclone and highest in the anti-cyclone, and its level sinks from the equator to the poles. The stratosphere is a region of interlaced currents and small vertical movements."

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* The Free Atmosphere in the Region of the British Isles. M. O. 202, 1909, containing Report by W. N. Davis. See also Report by Gold and Harwood, B. A. A. S. meeting at Winnepeg, 1909.

The term *isothermal* has been applied to the region above 11 kilometers to distinguish it from the lower levels or troposphere in which "the vertical variation of temperature is about 6° C. per thousand meters."† The names advective and convective have also been suggested as indicating the modes of transfer of the air in the two great divisions of the atmosphere.

The work now in progress on the exploration of the upper air and the prevalent interest in aviation open a new era in aerology. The promise of the times is a more definite knowledge of pressures and temperatures at all levels. It is, therefore, of some importance that our present bewildering systems of notation should give way to one international nomenclature. Our present cumbersome and inadequate units should be replaced by others capable of conversion into absolute units and suitable for universal needs. We think the new unit, whereby atmospheric pressure is recorded in dynes, meets the requirements.

Temperature.

Since the time of Galileo temperature has been measured by the expansion of mercury in a glass tube. The unequal expansion is divided into degrees and values are based upon the position of two fiducial points. Without going into the evolution of present thermometric scales, it may be noted that Galileo had a scale of 360 degrees, the lowest point based upon some freezing mixture and the highest representing the warmest day of summer. Fahrenheit had several scales. In the one finally adopted the zero is based on the temperature of the coldest day of the year 1709 in northern Europe. Réaumur used melting ice and boiling water, dividing the distance into eighty degrees. Celsius, using the same points, divided the distance into one hundred degrees, with the zero at the boiling point. This scale is often referred to as identical with the Centigrade scale, but this is a mistake. Linnæus modified Celsius' scale, making the zero indicate the temperature of melting ice and one hundred degrees that of boiling water. This is the widely used Centigrade scale. Concerning the Fahrenheit scale it may be noted that it has practically lost place in scientific usage to-day. Furthermore, in all our thermometric scales the so called fixed points are not truly fixed.

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* Report of Aerological Congress at Monaco, 1909. Rotch in Science, vol. xxx, No. 763, p. 193–199, August, 1909.

† Gold and Harwood, B. A. A. S., 1909, p. 32.

These need further definition, and it may be well to emphasize somewhat how both fiducial points wander with change in pressure. We find, for example, on the summit of Mount Whitney* that the boiling point on an average summer day is 86° C. (186·4° F.). Likewise the zero, that of melting ice varies. It is raised by the decrease of pressure. Indeed, throughout the western half of our country and especially in mountain sections the thermometer scale is shortened at both ends. A degree of temperature then is not a constant quantity if the fiducial points are not definitely known. Furthermore even at sea level there are differences of pressure due to passing atmospheric disturbances, and the change is sometimes sufficiently great to cause a variation of several degrees in the boiling and the melting points. But a new thermometer scale is much needed for another reason, and that is to avoid minus signs. Over a large portion of the earth during several months of the year temperatures are expressed by means of a negative sign. In the upper air, temperatures of from −50° C. to −70° C. are not infrequent. To avoid this use of a negative sign it is proposed to record air temperatures hereafter on a scale, the zero of which shall be the absolute or natural zero, 273° below the zero of the Centigrade scale. The change is easily made, and any temperature on the Centigrade scale is readily given its new value by adding 273 degrees. In practice the first figure, 2, can be dropped as the degrees, 200 A. to 299 A., cover temperatures from −73° C. to 26° C.

Thus we have practically obtained the Kelvin or Absolute scale and the temperature is read as it would be given by a constant volume gas thermometer.

$$T \text{ equals } t + 273{\cdot}10^\circ \text{ C.}$$
$$T \text{ `` } t + 459{\cdot}58^\circ \text{ F.}$$

It is a scale that is largely independent of the properties of the material used. Dr. Shaw says† that "the use of the absolute as distinguished from the Centigrade scale is becoming increasingly common in scientific publications, not only in regard to subjects connected with very low temperature, such as the liquefaction of gases; but in other work also, on account of its direct application in formulæ connected with thermal radiation, thermodynamics and the gaseous laws, with all of which the investigation of the upper air is closely concerned."

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* A small observatory has just been built by the Smithsonian Institution at this point, which is the highest point in the United States, excluding Alaska, 14,502 feet. See paper "Mountain Sites for Observatories," Pub. Astronomical Society of Pacific, vol. xxi, No. 124, Feb. 1909, in which the writer gives data for Mt. Shasta and Mt. Rainier.

† British Meteorological Office, Pub. 202, pages 5 and 6.

Wind.

It seems desirable to abandon the use of compass points in designating wind direction and to use hereafter degrees, starting from true north as the zero point. The new system eliminates the possibility of confusion of the terms east and west and also saves time in trigonometrical work and computing. The air in motion, or wind, will be regarded as flowing in to the center. For example, the wind previously recorded as northeast, because of blowing from that direction, will now be recorded as 45°. Velocities are to be recorded in meters per second.

Humidity.

As at present recorded, the moisture of the air is expressed in terms of relative humidity. This is at best a ratio and means different amounts of water vapor present with different temperatures. The absolute humidity, or weight of vapor in grams, is sometimes given. Likewise the vapor pressure. It would seem best to abandon the relative humidity and hereafter give the weight of water vapor in grams per thousand cubic meters of space. There should also be some means of representing the pressure of saturated aqueous vapor at the given temperature.

Miscellaneous.

There should also be suitable units for recording amounts of solar energy absorbed and radiated; also popular units for hours of sunshine and percentages of the possible. Precipitation should be recorded in millimeters and snow in its water equivalent. Cloud heights and cloud velocities should be given in the metric system.

A few of the new units and symbols employed follow:

F_b equals pressure in units of force, base 1,000,000 dynes
b “ one megadyne, or *bar*
db “ decibar
cb “ centibar
mb “ millibar
B_1 “ pressure at 106 meters, equals $750{\cdot}1^{mm}$ (29·532 inches)
B_0 “ “ “ sea level, “ 760·0 “ (29·92 inches)
W_1 “ weight “ B_1 “ 1019·8 grams per sq. cm.
W_0 “ “ “ sea level, “ 1030 grams per sq. cm.
H “ height of homogeneous atmosphere above B_1 .... equals $788{,}504^{cm}$
T “ 273 C. plus *t*.
R “ gas constant for air, “ 2,832,250

C_p equals specific heat of air, equals 9,804,000
C_v “ “ “ “ “ 6,971,750
k “ $\frac{C_p}{C_v}$ .... “ 1·4062486
A “ heat equivalent of work “ ·0000002389
$\frac{1}{A}$ “ mechanical equivalent of heat 42,683·7
H_c “ height of convective surface
T_c “ temperature at H_c
P “ specific weight of air .... ·00129305
P_{av} “ “ “ “ water vapor ·00080427

Note (added August 10, 1910).

Through the courtesy of Professor Charles F. Marvin and Mr. C. F. Talman, Librarian of the Weather Bureau, the following references have been found, proposing the use of C. G. S. units in measuring atmospheric pressure:

B. A. A. S. 1888 meeting, page 28. A committee of the British Association proposed the use of the *Barad*, pressure of one megadyne per square centimeter.

Monthly Weather Review, vol. xxvi, 1898, page 314, Cleveland Abbe discusses measurement of pressure in standard units of force.

C. E. Guillaume proposed to International Congress of Physicists in 1900, use of megadyne under the name *Barye*; and this was favorably reported by a committee of the Congress. (Travaux, Congr. Int. Phys., Paris, 1900, t. iv, pp. 61–62.)

Sandström and Helland-Hansen in their report on Marine Investigation, dated 1902, used the megadyne and the unit of atmospheric pressure and also for hydrostatic pressure.

Bjerknes and Sandström, in 1906, used the unit *bar* as mentioned by Köppen, Quar. Journ. Roy. Met. Soc., April, 1909.

During the present year Köppen, Shaw, Gold, Harwood, Dines and others used the bar.

ART. XXXI.—*Gageite, a New Mineral from Franklin, New Jersey;* by ALEXANDER H. PHILLIPS.

ATTENTION has been drawn to the probable existence of another new mineral from this locality by Prof. Penfield in his description of leucophœnicite,* but as very little of the same material came to the surface from the mine until the fall of 1909, nothing further was ever done in the matter. For the last six months Mr. R. B. Gage of Trenton, N. J., for whom the mineral now described is named, has been collecting material for an analysis. Through the aid of Col. W. A. Roebling of Trenton, who was willing to sacrifice his best specimen, ·04 of a gram of well-crystallized material were obtained, and used by Mr. Gage with the results here given:

			Ratio.	
SiO_2	24·71	·412		1·49
MnO	50·19	·707	1·109	4·00
ZnO	8·76	·107		
MgO	11·91	·295		
H_2O	[4·43]	·246		·9
	100·00			

Letting R stand for the metallic oxides, the ratio of SiO_2 : RO : H_2O is as 1·49 : 4 : ·9, yielding the formula $(RO)_8 (SiO_2)_3 \cdot 2H_2O$. Just how the water is related to the oxides, there was not enough material to determine, as in fact the water in the analysis is determined by difference. A large amount of the burden of error will therefore lie in that portion of the analysis; it is certain, however, that there is considerable water in the molecule. From the empirical formula, gageite would seem to be closely related to leucophœnicite, if not one of the probable series mentioned by Prof. Penfield.

Before the blowpipe the clear crystals assume at once a light bronze color, which darkens on further heating to a deep bronze, or nearly black, but they do not fuse. In the closed tube it yields water with the same change of color. The crystals dissolve at once in warm dilute nitric acid; upon heating this solution after the addition of a little silver nitrate and a small crystal of ammonium persulphate a very distinct permanganate color is obtained; a single small crystal will yield this test.

All the specimens of gageite thus far obtained are from the Parker Shaft. It is well crystallized, the crystals are clear and colorless, with a high vitreous luster, delicate, acicular and hair-like, often radiated and grouped in bundles extending out from the walls of small cavities, not unlike the habit of millerite. It may occur as a matt of interlocking crystals, or fan-shaped groups. Under the microscope the prism angles seem to be well developed, and several of the larger crystals are terminated by a pyramid. While no measurements of the angles have as yet been attempted, it is hoped that the crystalline elements and the important forms may be established in the near future from the material at hand.

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* This Journal, viii, 351, 1899.

The specimens thus far found have been associated with crystalline zincite, green willemite, calcite, while leucophœnicite has always been present, serving as a support for the gageite crystals. The same combination of agencies which produced leucophœnicite has also produced gageite, but as the ultimate product of crystallization.

Princeton, N. J., June 6, 1910.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Carbon Monosulphide.*—This compound, which is analogous to carbon monoxide, and which would be expected to be a gas, was described by Sidot in 1872 as a remarkably stable red powder produced by the action of light upon carbon disulphide. **SIR JAMES DEWAR** and **H. O. JONES** have now, for the first time, made the compound by the use of a chemical double decomposition, using for the purpose nickel carbonyl and thiophosgene. These react in the presence of a solvent, such as dry ether, carbon tetrachloride or chloroform, apparently according to the equation

$$Ni(CO)_4 + CSCl_2 = NiCl_2 + 4CO + CS,$$

or rather according to a multiple of this equation, since the product is evidently a polymer $(CS)_x$, because it is a solid rather than a gas. The product thus obtained agrees with Sidot's product in some respects, but it differs from it in some ways. It is a brown powder having a specific gravity of 1·6, but after compression into a solid block it gave the value 1·83. It is practically insoluble in alcohol, ether, benzene, and petroleum ether; it is slightly soluble in carbon disulphide, ethylene dibromide, nitrobenzene, naphthalene and phenol, giving deeply colored, reddish brown solutions. It is not soluble in dilute sulphuric acid, but in the concentrated acid it dissolves, forming a brownish purple solution, the color of which is only slowly destroyed at the boiling point of the acid. Upon dilution with water the solution in sulphuric acid gives a precipitate of the unaltered compound. It dissolves in concentrated nitric acid at ordinary temperature and the color of the solution is only destroyed by long heating. It dissolves in aqueous or alcoholic solutions of ammonia, ammonium sulphide, caustic potash and potassium sulphide, giving deep brown solutions from which acids precipitate it apparently unchanged. When the solid was heated in a high vacuum practically no change took place below 360° C.; at a red heat carbon disulphide was given off, but even after long heating at this temperature the residue, consisting largely of carbon, still contained a considerable amount of sulphur. On heating the carbon monosulphide in a current of dry hydrogen, hydrogen sulphide was produced and the residue was almost free from sulphur.

In a subsequent communication the same authors have described the preparation of what appears to be carbon monosulphide by the action of the silent electric discharge upon carbon disulphide vapor at the temperature of liquid air. At this low temperature a very low boiling, unpolymerized carbon monosulphide seems to be produced, and this possesses the remarkable property of spontaneously polymerizing at a slightly higher temperature with explosive violence and forming a brown powder.—*Chem. News*, cii, 49 and 61. H. L. W.

2. *The Action of Carbon-Tetrachloride upon heated Anhydrides, Oxides, and several Minerals.*—This method of simultaneously reducing oxides and forming chlorides has been the subject of many investigations for more than twenty years. **Camboulives**, however, has recently studied the process systematically, using a large number of oxides. The substances were placed in a boat within a tube of Bohemian glass, heated by means of a combustion-furnace, and vapor of carbon tetrachloride was passed through the tube. The temperature at which the reaction commenced was found by the use of a Le Chatelier thermo-electric couple placed within the tube near the boat. Care was taken to use as far as possible substances of the same degree of pulverization, but it was impossible to obtain the same porosity in all cases. For instance, the alumina prepared by the ignition of ammonium alum was readily attacked, while natural corundum was acted upon slowly and incompletely.

It was found that the temperatures of reaction are usually low, varying from 215° C. (with niobic anhydride) to 580° C. (with chromic oxide). The product in almost all cases is a chloride, for among the thirty oxides that were attacked only the oxides of niobium and thorium gave oxychloride, which in both cases was mixed with chloride. The process is well suited not only for the formation, but for the practical preparation of many anhydrous chlorides, especially those of the rare earth metals, chromium, nickel, vanadium, titanium, zirconium, beryllium, cadmium and cobalt.

Two oxides, silica and boracic anhydride, were found to be unattacked by the operation under consideration, but certain silicates are attacked to a degree apparently inversely proportional to their richness in silica, and the hydrous silicates are completely transformed into chlorides. Hence a mixture of clay and sand may be analyzed in this way, since the silicate of alumina forms the volatile chlorides of silicon and aluminium, and the sand is left behind.—*Bulletin*, IV, vii, 616. H. L. W.

3. *A New Method for Separating Tin and Antimony.*—In connection with an investigation in which a number of acid fluorides were prepared, **Fischer** and **Thiele** have observed that antimonic and stannic acid fluorides are different in their behavior with hydrogen sulphide. A solution containing tin and antimony is first oxidized, so that the metals are in the stannic and antimonic conditions; then the sulphides are precipitated with hydrogen sulphide and dissolved in hydrofluoric acid. In this solution hydrogen sulphide precipitates reddish brown antimonic sulphide, leaving the tin in solution. By evaporating this solution in a platinum dish with sulphuric acid until the hydrofluoric acid has been expelled, and taking up the residue with water,

a solution is obtained from which the tin may be precipitated with hydrogen sulphide. It does not appear that the method has been tested by quantitative experiments, but the results are interesting in indicating the possible interference of hydrofluoric acid in analytical operations where tin is present.—*Zeitschr. anorgan. Chem.*, lxvii, 315. H. L. W.

4. *Manufacture of Ethyl Alcohol from Sawdust.*—It is stated that ethyl alcohol—not methyl, or wood alcohol—is being made from sawdust on a large scale in France, and that the process will soon be put into operation in the United States and Canada. The process was invented by Dr. ALEXANDER CLASSEN of Aachen, Germany, and consists in heating the sawdust under pressure with water and sulphurous acid, thus converting the cellulose into fermentable sugar. The sulphurous acid is then drawn off, a certain amount of acetic acid formed at the same time is distilled off and saved, and the liquor separated from the residue is neutralized, fermented, and distilled. It is claimed that the insoluble residue of the process may be used as food for stock, and that 30 gallons of alcohol may be made from a ton of sawdust.—*Chem. News.*, cii, 41. H. L. W.

II. GEOLOGY AND NATURAL HISTORY.

1. *The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission. Volume II. The Mechanics of the Earthquake;* by HARRY FIELDING REID. Pp. viii, 192; with 2 plates and 62 figures. Washington, D. C., 1910. Published by the Carnegie Institution.—This second volume of the report of the California Earthquake is of great scientific interest.* It consists of a first part on the phenomena of the megaseismic region, a second part on the instrumental records of the earthquake, and an appendix on the theory of the seismograph. The purpose of the review will be to give a summary of some of the conclusions of general interest contained in the first two parts.

In discussing the permanent crustal displacements resulting from the earthquake, it is noted that the shifting at the San Andreas fault line amounted to about 6 meters, the southwestern side moving northwest. The geodetic surveys carried on from 1874–1892 and in 1906–1907 showed that the Farallon Islands, 37 kilometers southwest of the fault, had moved northward 1·8 meters. The movement of the latter Reid does not regard as accomplished at the time of the shock, but as going forward gradually and accompanying the accumulation of the stresses which were finally relieved at the time of fracture. That is, two-thirds of the stress which caused the rupture had already accumulated 25 years ago, and 50 years ago, as shown by the surveys of

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* See G. K. Gilbert, this Journal, xxvii, 48.

1851–1865, the elastic strain, which caused the rupture in 1906, had already accumulated to nearly half its final amount. It seems not improbable, therefore, that the strain was accumulating for one hundred years.

The distribution of the distortion of the rock resulting from the earthquake shows that the previous strain was highly concentrated within a few kilometers of the fault line. The strain per unit area must rise to a certain value before fracture results. If the strain had extended over a wider zone, a greater displacement would have occurred at the time of fracture. Since, however, the throw of six meters is a large one for an earthquake, it seems conclusive that in fault movements in general the preceding strain between the adjacent crust blocks is confined to a relatively narrow zone.

Reid next considers the possibility of the prediction of earthquakes by measuring the growing strains in a fault zone. For this purpose a line of piers should be built, say a kilometer apart, at right angles to the direction of the fault line. Starting from a time when the zone is comparatively free from strain, as is to a large extent true in the San Andreas rift at the present time, geodetic measurements at intervals of some years would determine the amount of growing distortion in this line at right angles to the fault. When the surface becomes strained through an angle of about 1/2000 we should expect a strong shock to relieve this strain. It seems probable that a very long period will elapse before another important earthquake occurs along that part of the San Andreas rift which broke in 1906 ; for we have seen that the strains causing the slip were probably accumulating for one hundred years. It is quite possible, however, for strong earthquakes to occur on neighboring faults after short intervals. The ruptures of the Haywards fault in 1868 and of the San Andreas fault in 1906 are fair examples, though the interval is rather long. The Haywards fault passes through Berkeley, and is 30 kilometers northeast of the San Andreas fault.

The second part of this volume deals with the instrumental records of the earthquake. On account of the great energy of this earthquake it was recorded by seismographs in all parts of the world, and these seismograms supply a large amount of data. The first topic considered is that of the increasing duration of the disturbance as the distance of the station from the origin is greater. The major reason for this is that the longitudinal waves travel faster through the earth than do the transverse waves, but Reid suggests in addition the analogy of a clap of thunder, which although a sudden crash at its point of origin is heard at a distance as a prolonged reverberation. Reflections of the elastic waves from the many surfaces in the outer zone of the crust serve to prolong and mix the vibrations, but with each reflection a partial transformation of the wave motions is produced, a wave motion of a single character being reflected as partly longitudinal, partly transverse vibrations. Consequently the waves become mixed in nature as well as in duration. Such mixing is, however, doubtless a phenomenon attending the passage of the waves through the outer shell of the crust only, so that clear distinctions between the first and second preliminary tremors and the main waves are not lost. Plotting of the times of beginning of the first and second preliminary tremors and of the principal part indicate clearly that the first two are transmitted through the earth, the latter around the earth. As the times of transmission through the earth are dependent upon the changes in the nature of the centrosphere dependent upon depth the preliminary tremors are of great interest. Unfortunately at distances greater than 100° for the first preliminary tremors and 125° for the second preliminary tremors, the observations of the phases become extremely doubtful. This further emphasizes the importance of installing instruments recording the vertical component of motion, and instruments with high magnifying powers, not less than 100.

Following Wiechert's method, the curves representing the normals to the wave fronts and the velocities at various depths are computed from the data of the seismograms. As shown in fig. 28 of the report, the velocity of the longitudinal waves increased rapidly with depth, but with decreasing rapidity, from $7{\cdot}2^{km}$ per sec. at the surface to $12{\cdot}5^{km}$ per sec. at 2170^{km} from the surface, ·66 of the radius from the center. Below that depth the velocity is nearly constant. The velocity of the transverse waves is $4{\cdot}8^{km}$ per sec. at the surface and increases almost linearly with depth, reaching a velocity of about $7{\cdot}5^{km}$ per sec. at half the distance to the center of the earth. The absence of good records from distances beyond 125° prevents a knowledge of the velocities at greater depths. Within the limits regarding which information is given, Reid remarks that there is no indication of a sudden change in the velocity of either wave such as we should expect if there were any sudden changes in the nature of the earth's interior.

In discussing the surface waves the most important point is to determine the time when they begin. This is chosen by Reid where the irregular movements due to the second preliminary tremors give place to regular waves with a long period (30 to 50 seconds). The velocity of transmission is uniform along the great arcs of the earth and the seismograms of the San Francisco earthquake give 88 minutes as the time to reach the antipodes. No variations in velocity along different paths are to be detected greater than the errors of observation. Thus the velocity under the Pacific ocean to Japan is the same as under North America and the Atlantic ocean to Europe.

On comparing these results with those of Milne in 1902 and Oldham in 1900 it is seen that the preliminary tremors are for the greater part of the curve about 2 minutes earlier, apparently from lack of accuracy in the earlier observations. Determinations of velocities given by different great earthquakes are shown to be of great supplemental value, since the best seismographs give records which are in consequence at different distances from the origin.

In regard to periods and amplitudes: many periods are present during the first and second preliminary tremors and the instruments single out and make prominent those which are near the period of the instrument. The periods of the first tremors are mostly limited to a quarter of a minute, of the second tremors mostly between a quarter and a half of a minute. The amplitudes of the first tremors range about one-tenth those of the second. They are measured on the average by tenths and hundredths of a millimeter respectively at distances between 20° and 100° from the origin. The periods of vibration of the regular waves were in general not very far from 30 seconds. In the megaseismic region the amplitudes were 50^{mm} or more; at distances of 30° to 50° they have diminished to about 5^{mm}, and we must go as far as 100° or so to find amplitudes less than 1^{mm}. We see, therefore, that the great world-shaking earthquakes cause movements of the earth at great distances which are by no means inconsiderable, and the only reason why they are not felt is that the period, and, therefore, the movement is too slow to make them evident to our senses. In conclusion, Reid points out the importance of damped instruments, of a high magnifying power and an open time scale. It is from instruments possessing these qualities that future increases in this branch of knowledge are to be expected.

The third part, on the theory of the seismograph, although of great importance is of more particular interest to specialists in earthquake phenomena. J. B.

2. *West Virginia Geological Survey. County Reports and Maps. Pleasants, Wood, and Ritchie Counties;* by G. P. GRIMSLEY. Pp. xiv, 352, with 21 plates, 16 figures, and 3 maps in atlas. Also, *Map of West Virginia* (as a separate publication), scale 7 miles to the inch, showing coal, oil, gas, and limestone areas, by I. C. WHITE. Morgantown, West Virginia, 1910.—This report by Professor Grimsley gives very complete information regarding the three counties named and is of practical as well as scientific value. The chief resources of the region lie in its soils derived from the Permian shales and sandstones and in the abundant accumulations of petroleum. J. B.

3. *Supplementary Investigation in 1909 of the Figure of the Earth and Isostasy;* by JOHN F. HAYFORD, Inspector of Geodetic Work, and Chief, Computing Division, Coast and Geodetic Survey. Pp. 80, 5 maps in pocket. Washington, 1910.—The noteworthy contribution by this author on "*the Figure of the Earth and Isostasy*" has been reviewed in the number of this Journal for February, 1910. The first paper embraced the results of observations up to 1906. In this supplement, the results are confirmed and made more accurate, embracing observations up to 1909 and including some improvements in method. The number of astronomical determinations employed in the first

computation was 507, in the second it was 765, including those of the first. The final values of the equatorial radius of the earth compared to previous determinations are as follows:

Clark, 1866	6,378·206	meters
C. and G. Survey, 1906	6,378·283 ± 34	"
C. and G. Survey, 1909	6,378·389 ± 18	"

The values for the depth at which isostatic compensation becomes complete are eight per cent greater than in the determinations from the first paper. Some discussion and several charts are also given of areas of excessive and deficient density in the United States. The geologic importance of the geodetic study of these local departures from isostatic equilibrium is obvious, but the work has as yet hardly advanced to sufficient completeness to enable comprehensive conclusions on this subject to be drawn.

J. B.

4. *The Gold Hill Mining District of North Carolina;* by F. B. Laney. Bull. No. 21, North Carolina Geol. and Econ. Surv. Pp. 119, 23 plates, 5 figs.—The Gold Hill Mining District lies in the south-central portion of the state in Rowan, Cabarrus and Stanley counties. The principal surface features are a long, low-lying, flat-topped ridge, the Gold Hill Ridge and a series of hills, the Beaver Hills. The rocks of the district are about equally divided between the sedimentary and igneous groups. The sedimentary series, consisting of slates, tuffs and breccias, intercalated with which are minor flows of rhyolite and andesite, makes up its southeastern portion. The igneous rocks, which lie in the northwestern half, consist chiefly of a much metamorphosed basic effusive rock, called a greenstone, into which diorite and granite have been intruded. These two rock series are separated from each other by a great fault, the Gold Hill fault, which extends across the district in a northeast direction. This fault is marked by a zone of highly crushed and schistose rocks, much minor and local faulting and numerous closely spaced joints. There is much folding of the sedimentary rocks, particularly near their contact with the igneous area.

The ore-bearing veins are developed in the zone of minor faulting to the east of the Gold Hill fault. They appear for the most part to follow the trend of the fault, but are often found following the strike of the schistosity. They are of two types, one of which is marked by an extensive silicification of the wall rock and is largely gold-bearing with only small amounts of copper. The other presents a minimum of silicification and consists of a zone of narrow rifts in the slate parallel with the schistosity. This series carries chiefly copper with only small amounts of gold. The ores are chiefly auriferous pyrite and chalcopyrite. In general the pyrite is the older mineral, and after deposition was more or less shattered by further movements. This shattering was followed on the one hand by the deposition of chalcopyrite and more pyrite, and on the other by the introduction of pyrite and gold, the auriferous pyrite. It is believed that the two series of veins represent two distinct periods of mineralization or possibly two sources for the ore-bearing solutions. W. E. F.

5. *University of Illinois Bulletin.* Vol. 7, No. 2. September 13, 1909. Chemical and Biological Survey of the Waters of Illinois: Report for year ending December 31, 1908. EDWARD BARTOW, Director. Pp. 204. Water Survey Series, No. 7. Urbana, Illinois.—This bulletin is of much local importance, containing as it does an examination of many thousand samples of water from different sources. It is noted that up to the close of 1908 the State Water Survey received 18,700 samples of water for examination. Not only the results of analyses themselves are given, but also several chapters dealing with general topics, as the determination of nitrates in drinking water, the methods of water analysis, etc.

6. *The New Bureau of Mines of the United States Geological Survey.*—The Bureau of Mines, recently established as a part of the U. S. Geological Survey, began its work with the first of July. This Bureau will have charge of the investigation of mine accidents and fuels, together with the personnel and equipment of these investigations; it also embraces the fully-equipped testing station at Pittsburg. The related investigations of the structural materials will be carried on by the Bureau of Standards. An appropriation of $310,000 has been made by Congress for the investigations of mine accidents, and $100,000 for the analysis and testing of the various fuels; the total appropriations for the Bureau of Mines, including salaries, rent, etc., amount to $502,200.

It is stated that "the work of the Bureau of Mines for the first year will be a continuation and expansion of the work carried on by the Technologic Branch of the Geological Survey. The law in itself provides for a variety of other problems that properly belong to the Bureau of Mines and which should eventually be undertaken, such as methods of mining and metallurgical processes, but these activities will be deferred for the most part until Congress gives additional authorization in the shape of adequate appropriations. The spirit of the debates in Congress, both on the Bureau of Mines legislation and on the appropriation items, emphasized the desire to regard the mine accidents investigations as urgent, and this will be the feature of the work."

The mine accidents investigations, begun by the Geological Survey in 1908, have already accomplished important results. Since 1908 "investigations of explosives, coal, gas, dust, electricity, and other possible causes of mine explosions have been continually under way. The mining engineering field force of the Geological Survey has already made decided progress in the study of underground mining conditions and methods. Practically all of the coal mines in which mine explosions have occurred during the last two years have been carefully examined, the gases, coke and dust have been analyzed at the laboratory at Pittsburg and every effort has been made to determine the explosibility of various mixtures of gas and air in the presence of shots of different types of explosives. Considerable progress has also been made in the investigation of explosives used in coal mining, and the conditions under which they may be used with least risk. Manufacturers have submitted many explosives for test at the station, and a considerable portion of them passed and have been classified among the permissible explosives. The investigations and educational work in connection with the use of artificial breathing and other types of mine rescue equipment, the so-called oxygen helmets, have not only been useful in developing a more satisfactory use of such equipment in the examination of mine explosions, but also better methods for using this equipment in mine rescue work."

The publications of the Survey relating to mine and fuel investigations, those prepared by the Technologic Branch, will in the future be distributed by the Bureau of Mines, but the publications relating to structural materials will continue to be distributed by the Geological Survey. The last of the bulletins of the Technologic Branch to be published by the Survey relates to the Explosibility of Coal Dust, and was prepared by G. S. Rice, with chapters by J. C. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. The titles are given of a series of bulletins to be issued by the Bureau of Mines in the near future.

7. *The Evolution and Function of Living Purposive Matter;* by N. C. MACNAMARA. Pp. xi, 298. New York, 1910 (D. Appleton & Company: The International Scientific Series).—The book consists of two distinct parts, the first 187 pages containing a discussion of the evidence leading to the conclusion that the psychic nervous substance of the brain of the higher animals has been derived by a process of evolution from matter in the simpler organisms possessing only instinctive functions. An attempt is made to trace this gradual development of the purposive elements of the protoplasm in the most lowly forms of life into the specialized substance of the cerebrum of the human being. The nature of protoplasm and its relation to the hereditary qualities of the individual are discussed at length.

In the second portion there is given a remarkable illustration of the importance of heredity in determining individual character. This is shown by the history of the Celtic people, who lived in a nearly constant environment for 1200 years from the time of their settlement in Ireland about the year 450. The destinies of the individuals and of the race are shown to have been correlated with the inheritance of personal characteristics through successive generations. W. R. C.

8. *Discussion on the Origin of Vertebrates;* by W. H. GASKELL, E. W. MACBRIDE, E. H. STARLING, E. S. GOODRICH, H. GADOW, A. SMITH WOODWARD, ARTHUR DENDY, E. RAY LANKESTER, P. CHALMERS MITCHELL, J. STANLEY GARDINER, T. R. R. STEBBING, and D. H. SCOTT. Reprinted from the *Proceedings of the Linnean Society of London*, pp. 9–50, 1910.—Two successive

meetings of the Linnean Society of London, on January 20 and February 3, of the present year, were devoted to the discussion of this topic. Dr. Gaskell first presented his much criticized theory maintaining an origin from an arthropod ancestor. In reply Prof. MacBride stated his objections to Gaskell's theory and supported the well-known hypothesis of the Balanoglossus-Amphioxus route of development. The further discussion consisted largely of objections to the one theory or the other, but in the main Gaskell's hypothesis was held to be founded rather on superficial resemblances than on ancestral relationships. Although the problem was as far from solution at the end of the two meetings as at the beginning, the published discussion affords the best criticism of the theories involved that has yet appeared, the subject having been briefly reviewed from the standpoint of the anatomist, physiologist, embryologist, paleontologist, and botanist. W. R. C.

9. *The Vegetable Proteins ;* by THOMAS B. OSBORNE. Pp. xxiii, 125. New York and London, 1909 (Longmans, Green & Co.).—In this little volume, which forms one of a series of monographs on biochemistry, edited by R. H. Aders Plimmer and F. G. Hopkins, the author confines himself to a discussion of the general and physical properties of the vegetable proteins. All students of chemistry will welcome this opportunity of securing from the pen of a recognized authority a simple and readable presentation of what has thus far been learned of one of the most difficult branches of the subject. W. R. C.

10. *The Science and Philosophy of the Organism* (Gifford Lectures) ; by HANS DRIESCH. Volume II. Pp. xvi, 381. London, 1908 (Adam and Charles Black).—In the first volume of this important work on philosophical biology the chief results of analytical biology were discussed in their bearing on morphogenesis, adaptation, inheritance, systematics, and history. This discussion is concluded in the first 124 pages of the present volume, in which the nature of organic movements is considered. The second section of the work, entitled "The Philosophy of the Organism," discusses the philosophy of nature in general, the characteristics of entelechy, entelechy and univocal determination, entelechy and causality, entelechy and substance, the direct proof of the autonomy of life based upon introspective analysis of complete givenness, individuality, the problem of universal teleology, and metaphysical conclusions. W. R. C.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *British Association for the Advancement of Science.*—The annual meeting of the British Association was held at Sheffield during the first week of September; some 1400 members were in attendance. The inaugural address, delivered by the President, Prof. T. G. Bonney, was devoted to an interesting discussion of "Some aspects of the glacial history of Western Europe." The

meeting of next year will be held at Portsmouth with Sir William Ramsay as president, and Dundee has been appointed as the place of meeting in 1912. In 1914 the Association will meet in Australia.

2. *Carnegie Institution of Washington.*—Recent publications of the Carnegie Institution are noted in the following list (continued from p. 94).

No. 53. Egyptological Researches. Vol. II. Results of a Journey in 1906; by W. MAX MÜLLER. Pp. v, 188, 47 plates.

No. 109. Medusæ of the World; by ALFRED GOLDSBOROUGH MAYER. Vol. I. The Hydromedusæ. Pp. 230, xv; 29 plates, 119 figures. Vol. II. The Hydromedusæ. Pp. 231–498, xv; figures 120–327, plates 30–55. Vol. III. The Scyphomedusæ. Pp. iv, 499–735; figures 328–428, plates 56–76.

No. 122. Determinate Evolution in the Color Pattern of the Lady-Beetles; by ROSWELL H. JOHNSON. Pp. iv, 104, 92 figures.

No. 124. List of Documents in Spanish Archives relating to the History of the United States, which have been printed or of which transcripts are preserved in American Libraries; by JAMES ALEXANDER ROBERTSON. Pp. xv, 368.

No. 126. The Metabolism and Energy Transformations of Healthy Man During Rest; by FRANCIS G. BENEDICT and THORNE M. CARPENTER. Pp. viii, 255.

No. 129. The Conditions of Parasitism in Plants; by D. T. MACDOUGAL and W. A. CANNON. Pp. iii, 60, 2 figures, 10 plates.

3. *Les Theories Modernes du Soliel;* par J. BOSLER, Astronome a l'Observatoire de Meudon. Pp. 382. Paris (Encyclopédie Scientifique, Octave Doin).—This volume deserves notice not merely for its individual excellence, great as that is, but still more because of its place in the series of volumes constituting the Encyclopédie Scientifique, which has already been noticed in this Journal in connection with another volume in the same subdivision of this great enterprise.

This is a handy volume Encyclopedia in numbers of pocket size aggregating eventually some 1000 volumes classified in 40 divisions or libraries, each library in charge of a specialist and comprising 20 to 30 volumes.

The number under review is the third of the set of 27 belonging to the library of Astronomy and Celestial Physics and is compiled by Bosler, astronomer of the observatory of Meudon, among the foremost of observatories in solar research since photography and the spectroscope have been available to unveil solar mysteries.

The work is as judicious and authoritative as its source would lead us to expect, and is written with the clearness and precision for which French scientists are preëminent.

The subdivision of this encyclopedia into 1000 volumes is with a view to continual revision as the progress of science requires, nowhere more necessary than in the science of solar physics, constructed as it is from the residuum of numberless evanescent guesses.

W. B.

4. *Celestial Ejectamenta;* by HENRY WILDE, D.Sc., D.C.L., F.R.S. Pp. 34 with 4 plates. (The first Halley Lecture at the University of Oxford.)—The lecture consists mainly of a number of novel propositions, for the most part stated without adducing proofs other than references to lectures or pamphlets of the author bearing on them. Most noticeable of these are the following:

Simplification of the theory advanced by Halley that terrestrial magnetism is due to rotation of the earth's interior (presumably plastic) relative to the surface, with a differential (synodic?) period of 960 years (Halley, 700 years).

That periodic comets are planetary "ejectamenta" (i. e. volcanic products of the plastic period). The "Capture Theory" is ignored, and the reality of hyperbolic orbits denied.

That the "red spot" of Jupiter is a volcano, whose "ejectamenta" produce the Jovian belts in the form of fine dust like that ejected by Krakatoa.

That Bode's Law and a kindred but more accurate one, not here stated, discovered by the author and based on Mercury's heliocentric distance as the unit, are examples of a "law of binary progression" to which the series of atomic weights also conforms. The author asserts that this "law of binary progression" is one of the fundamental laws of nature, and that it admits of only a teleological explanation, and is an evidence stronger than any other known to science of a causal intelligence guiding the universe.

The deviation of Neptune from the place required by Bode's Law is explained as due to its perturbations by the inner planets, which perturbations, it is asserted, are cumulative rather than compensating, and will, therefore, eventually precipitate the planet upon Uranus. This, it is needless to point out, destroys the gravitational stability of the solar system and charges Laplace and Lagrange with folly. We agree with the lecturer that "it is not a little remarkable that the effect . . . never presented itself to writers on celestial mechanics who have elaborated the doctrine of the absolute stability of the solar system." W. B.

5. *Elementary Dynamics for Students of Engineering;* by ERVIN S. FERRY, Professor of Physics in Purdue University. Pp. 182. New York, 1910 (The Macmillan Company).—An excellent text-book for all college students preparatory to Physics as well as for those in Engineering, whether in connection with the Calculus or not. The methods are rigid without unnecessary refinement, the applications are numerous, fresh and pertinent, and the underlying principles of the science are presented distinctly by themselves and in a manner to show that they are not, as they are often made to appear to beginners, abstractions but generalizations from experience. W. B.

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VOL. XXX. NOVEMBER, 1910

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FOURTH SERIES

VOL. XXX—[WHOLE NUMBER, CLXXX.]

No. 179—NOVEMBER, 1910.

NEW HAVEN, CONNECTICUT.

1910.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

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Art. XXXII.—*Pleistocene Glaciation and the Coral Reef Problem*; by Reginald A. Daly.

Introduction.—During the last thirty years, most of the active students of atolls and barrier reefs have tended to oppose the Darwin-Dana hypothesis of extensive and prolonged crustal subsidence in the Pacific and Indian ocean basins. The borings at Funafuti do not seem to have proved the hypothesis even in the case of this one atoll. In Hinde's detailed description of the cores we read that, from the top down to the 150-foot level their material is chiefly coral. Of the remainder of the boring, 663 feet are noted as principally composed of detrital and foraminiferal matter; 279 feet carry small masses of coral, but the relative proportion of coral rock, as opposed to detrital and foraminiferal matter (here also abundant), is not stated; while only 22 feet, in all, of the core below the 150-foot level is described as originally solid coral rock.* These figures and, yet more clearly, the thoroughly particularized text of the report, suggest that the 1,114-foot boring penetrated—first, a true reef extending little deeper than the bathymetric limit of reef-building corals; and then, a much thicker talus deposit containing blocks of massive coral. At several of the deeper levels the corals found are stated to have been "probably in the position of growth," but no discussion of this principal conclusion is contained in the report. Though most of the material constituting a typical reef is not solid coral rock, the percentage of non-detrital coral rock in the Funafuti main boring appears to be much too low to prove the Darwin-Dana hypothesis.

On the other hand, Semper, Murray, Alexander Agassiz, and others have long contended that coral reefs have been formed either in areas of elevation or in areas of long-continued crustal repose; though Agassiz accounts for the depth of certain lagoons and channels through local, very moderate subsidence.

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* See Section xi of report on "The Atoll of Funafuti," London, 1904.

In the literature of coral reefs there is no systematic discussion of another possibility which must fundamentally affect the theory of coral reefs; namely, a positive movement of sea-level in the coral-reef zone of the earth, independently of crustal subsidence. The writings of Suess have now made this idea very familiar, and few geologists will be disposed to deny the validity of the principle. In the following pages the attempt is made to show that the melting of the Pleistocene glaciers in both northern and southern hemispheres resulted in a slow, relatively small, but theoretically important raising of sea-level throughout the intertropical zone. Most of the plateaus from which annular and barrier reefs rise are credited to Pleistocene marine erosion operating on Tertiary islands, shoals, or continental shores. The corals colonized those plateaus during late Pleistocene time and have since continued the reef growth. The atoll and barrier-reef forms were inevitable consequences of the late Pleistocene drowning.

This conception thus seems to supply a missing link in the chain of argument used by Semper, Rein, Murray, Agassiz, and Guppy against the wholesale-subsidence hypothesis. Darwin and Dana depended very largely on the visible forms of coral reefs in constructing their ingenious theory. If it can be shown that these forms were produced by increase of ocean water in the equatorial zone, the hypothesis of enormous crustal deformation beneath the coral archipelagoes is shorn of its strongest argument.

In one instance the writer has been successful in the search for earlier statements of the relations between Pleistocene glaciation and the forms of coral reefs. After describing evidences of the recent drowning of most islands and coasts, Penck writes: "The causes of the general rise of sea-level in the latest geological time might perhaps be connected with those climatic changes which the earth underwent in the Glacial period. If, during that time, northern Europe, northern North America, and the Antarctic regions were simultaneously glaciated, a considerable mass of water must have been removed from the ocean, and, if the thickness of ice be assumed as 1,000 meters, the sea-level must have been 150 meters below its present position."* The context of this passage gives no explanation of the flatness and nearly uniform depth of the plateaus on which the visible reefs have been built. Partly for this reason, Penck's suggestion has not received, in the recent writings on coral reefs, the attention it deserves. In any case, it is time for renewed emphasis on the vital connection between Pleistocene glaciation and the conditions of Pleistocene intertropical seas.

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* A. Penck, Morphologie der Erdoberflaeche, vol. ii, 1894, p. 660.

Effect of Pleistocene glaciation on intertropical sea-level.—It is becoming increasingly apparent that the southern hemisphere was affected by Quaternary glaciation contemporaneously with the northern hemisphere.* At the time of their maximum extension the ice-sheets, which have since melted away, covered a total area which may be estimated as from five to eight millions of square miles. One will not go far astray in assuming six millions of square miles as the area thus deglaciated on the earth as a whole. This is one twenty-fourth of the present area of the ocean.

The average thickness of the ice cannot yet be determined, but its order of magnitude can be stated. The depth and surface gradient of the Labrador ice-cap were sufficient to drive that sheet over the mountains of New England and New York state, and to give the effluent ice-streams crossing the Torngat mountains of northeastern Labrador thicknesses of more than half a mile.† The writer has found the maximum thickness of the Cordilleran ice-cap of North America at the 49th parallel of latitude—near the southern limit of the cap—to be over 6,000 feet, and the average thickness about 2,500 feet. The ice-cap of northwestern Europe varied between 1,500 feet in thickness at the Harz mountains to "perhaps between 6,000 and 7,000 feet" in thickness over Scandinavia, and "the sheet may have been as much as 4,000 or 5,000 feet thick in the northern part of Britain."‡ Penck has estimated that the average thickness of the Pleistocene ice was well over 1,000 meters.§

The removal of enough water to form these great sheets of ice would tend to lower sea-level all around the globe by the amounts here approximately stated:

Estimated average thickness of ice (in feet)	3,000	3,600	4,000	5,000
Corresponding decrease of ocean's depth (in feet)	125	150	167	208

Woodward, Hergesell, and others have shown that a second cause for a negative movement of sea-level in the equatorial zone is to be found in the gravitative power of the ice. Using Woodward's formulas, it may be calculated that, if the ice had an area of 6,000,000 square miles and an average thickness varying from 3,000 to 5,000 feet, the attraction of the ice would lower the level of the equatorial sea by amounts ranging from five to eight fathoms.*

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* Cf. H. Hess, Die Gletscher, Braunschweig, 1904, p. 396.

† See Bulletin, Museum of Comparative Zoölogy at Harvard College, vol. xxxviii, p. 251, 1902.

‡ Sir Archibald Geikie, Textbook of Geology, vol. ii, p. 1305, 1903.

§ A. Penck, Separatabdruck, Jahrbuch Geog. Gesell. zu München, vii, p. 30, 1882.

Taking the two effects together, the formation of the ice-sheets (which have since disappeared) would produce a negative movement of sea-level in low latitudes to an amount ranging between twenty-five and forty-five fathoms. Assuming 3,600 feet as the average thickness of the ice, the shift of level in the equatorial sea would be about thirty fathoms.† Conversely, the deglaciation of the full 6,000,000 square miles would raise the level in the equatorial zone by about thirty fathoms.

The Plateaus.—Can we connect the later, positive, movement of level with the forms of existing annular and barrier reefs? That question suggests another, as to the origin of the broad plateaus on which the reefs have been built.

A principal datum for the discussion of this subject must be the range of depths of the water above the plateaus. An approximation to those depths is given in the depths of the atoll lagoons and of the barrier channels. It is clear, however, in spite of Murray's hypothesis of solution as explanatory of lagoons, that the vast majority of lagoons and barrier channels are slowly filling up; so that the average depth of the plateau is somewhat greater than the average depth of the deeper part of lagoon or channel.‡ In the case of many a small atoll, which, on account of limited size, has been nearly filled with calcareous deposits, the plateau is many fathoms below the deepest hole in the lagoon.

The following table (col. 1) gives the maximum depths of water charted in representative atoll lagoons and barrier channels of the Pacific and Indian oceans.§ In some cases the depths are given for great plateaus bearing relatively few reefs. These depths are usually greater than the maximum depths in atoll lagoons and barrier channels, but are of the same order of magnitude. Column 2 shows the estimated average depths of the deeper and generally considerable parts of lagoons or channels.

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* R. S. Woodward, Bull. U. S. Geol. Survey, No. 48, 1888, pp. 41, 70, etc.

† Penck's estimate of 150 meters for this change of level seems too high, even if the volumes of the present Antarctic and Greenland ice-caps be included in the computation.

‡ Cf. W. J. Sollas, in "The Atoll of Funafuti," 1904, pp. 6 and 27; and R. Langenbeck, Die Theorieen über die Entstehung der Koralleninseln, Leipzig, 1890, p. 50 ff.

§ Nearly all figures in this table have been derived from Agassiz's very convenient reproductions of Admiralty and other charts, to be found in Bulletins Nos. 28 and 33, and Memoirs Nos. 28 and 29, of the Museum of Comparative Zoology at Harvard College (1898–1903).

	1 Max. depth (fathoms).	2 Mean depth in deeper part (fms.).	3 Extreme width (miles).	4 Extreme length (miles).	5 Exposure to waves (quadrants).
Great Barrier, Australia					
10–12° S. Latitude	32	15	72	--	2
12–14 "	27	15	35	--	2
14–16 "	34	20	33	--	2
16–18 "	37	20	35	--	2
18–20 "	36	22	65	--	2
20–22 "	37	25	100	--	2
Fiji Group					
Viti Levu, N. W. coast, barrier	46	35	30	--	2
" " E. " "	42	22	15	--	2
Vanua Levu, S.W. " "	49	35	15	--	2
" " N. " "	46	35	25	--	2
Wakaya, barrier	35	30	4	--	2
Mbengha. "	32	20	12	12	3
North Astrolabe Reef, barrier	18	10	3	4	4
Great " " "	31	20	6	10	3
Ngau, barrier	26	25	4	--	2
Nairai, "	26	18	3	5	3
Ringgold islands, atoll	52	40	6	30	4
Exploring islands, barrier	101*	40	10	25	3
Reid reef, atoll	20	18	6	7	4
Southern Argo reef, atoll	36	30	5	9	4
Hao, atoll (Paumotu group)	31	30	10	35	4
Gambier islands, barrier	38	18	6	7	2
Society Islands					
Tahiti, E. coast, barrier	31	20	1·5	--	2
" Taiaropu, "	30	25	1·5	--	2
Tahaa, barrier	27	20	2	--	2
Raiatea, "	33	20	2	--	2
Murea, "	27	20	1·5	--	2
Bora Bora, "	25	18	2	--	2
Huaheine, "	28	20	1·5	--	2
Tonga Group					
Nomuka group, plateau	ca. 48	40	20	25	4
Haapai " " (S. pt.)	ca. 50	40	16	25	4
Vavau " "	ca. 65	55	12	25	4
Vavau island, barrier	50	40	----	--	-
Funafuti, atoll (Ellice group)	30	25	9	14	4
Arhno, atoll (Marshall islands)	32	22	10	20	4
Truk islands, barrier (Carolines)	36	30	35	35	4
Maldive Group					
Ihavandiffulu, composite atoll	34	30	6	12	4
Tiladummati, " "	29	20	12	30	4
Miladummadulu, " "	32	28	18	54	4
N. Molosmadulu, " "	31	24	----	--	-
Middle " " "	26	20	20	60	4
South " " "	36	30	----	--	-
Fadiffolu, " "	32	28	18	24	4
North Male, " "	38	33	20	24	4
South Male, " "	37	30	10	20	4
Felidu, " "	40	35	14	28	4
Ari, " "	43	35	15	48	4
North Nilandu, " "	37	30	14	18	4
South " " "	39	30	12	20	4

* At a local, very narrow trough in the lagoon.

	1 Max. depth (fathoms).	2 Mean depth in deeper part (fms.).	3 Extreme width (miles).	4 Extreme length (miles).	5 Exposure to waves (quadrants).
Mulaku, composite atoll	42	35	15	25	4
Kolumadulu, " "	45	40	24	27	4
Suvadiva, " "	48	40	33	50	4
Makunudu, atoll	17	10	6	18	4
Horsburgh, "	23	20	4	9	4
Gaha Faro, "	22	20	4	7	4
Rasdu, "	23	18	4	5	4
Wataru, "	21	18	3	4	4
Addu, "	36	30	7	10	4
Haddumati, "	42	38	13	20	4
Great Chagos Bank,	50	40	60	90	4

Columns 3 and 4 give the respective extreme widths and lengths (in geographical miles) of atoll-bearing plateaus, and the width of the plateaus surmounted by barrier-reefs. Column 5 states the approximate degree of exposure of each plateau to marine erosion; the coasts with barrier reefs being generally exposed to waves from two quadrants; and atoll-bearing plateaus generally so exposed in all four quadrants.

The average maximum depth of the lagoons and channels is about 35 fathoms. The average depth of the great plateaus which bear relatively small areas of reef-rock is about 45 fathoms. The difference between the two averages, or 10 fathoms, may nearly represent the average depth to which the lagoons have been filled by calcareous matter since the existing reefs began to grow. Removing from the plateaus their veneers of solid reef-rock, coral detritus, and the exuviæ of algæ, foraminifera, etc., we should have something like 45 to 50 fathoms of water on each of these vast platforms. The relative uniformity of depth in each of the broader lagoons and the striking lack of strong variation in the depths of greater lagoons and barrier channels all around the world, would be at least matched by the uniformity of depths on the plateaus so uncapped.

In explanation of the smoothness of the plateaus and of their steady adherence to the average depth of about 45 fathoms, neither the Darwin-Dana hypothesis of prolonged subsistence nor the Murray hypothesis of solution is adequate. In his last volume Suess writes: "Notwithstanding the valuable investigations quite recently made, and notwithstanding the objections which such distinguished investigators as Semper, Murray, Agassiz, and so many others have raised to the views of Darwin and Dana, it must still be admitted that the depth of the enclosed lagoon has not yet been completely explained. Thus, the view that the crown has been built up by corals during positive movement has still some foundation."*

That the plateaus are due to erosion, coupled with the deposition of the eroded material as an advancing submarine talus, seems to be the preferable explanation. A full discussion of the point will not be made here, as it would demand many pages compiling the arguments of the older hypotheses and would thus unduly lengthen the present note. Suffice it to say, that in crediting the forms and hypsometry of the plateau surfaces essentially to marine abrasion, we make the only assumption which seems able to match all the facts.

It is not likely that the plateau surfaces were shaped when sea-level had its existing relation to the general sea bottom. Even the Pacific breakers cannot effectively erode the bed-rock of a broad shelf with depths approaching 45 fathoms. It is hard to believe that they could lower the plateau surfaces to such depth in any permissible time.

On the other hand, the conditions for the development of the platforms by marine abrasion were met during the Glacial period. For a large part of that epoch the level of the intertropical ocean was about 30 fathoms lower than now. Chamberlin and Salisbury have estimated that the length of the Glacial period was from 300,000 years to more than 1,000,000 years.† The entire time during which there was heavy glaciation, comparable to that of the maximum ice-caps, must have been much more than 100,000 years. The Pleistocene islands were subjected to the attack of waves and currents operating near a sea-level which shifted up and down with the maxima and minima of glaciation; but we may conceive that the net result was the preparation of broad benches and platforms at depths ranging from zero to fifteen or twenty fathoms below the last of the low Pleistocene sea-levels.

In a second principal way the Pleistocene conditions of abrasion in the equatorial ocean probably differed from those now ruling in the same latitudes. Some of the best authorities on the Glacial period hold that the whole surface of the earth was chilled during that time.‡ A fall of only half a dozen degrees in the average temperature of the intertropical seas would make an enormous difference in the distribution of the stenothermic reef-corals, which cannot withstand a winter temperature below 20° C. The February marine isotherm of 20° lies but a few hundred miles north of the larger Hawaiian islands. We may be certain that those islands were not bordered by living reefs at a time when 4,000,000 square miles of ice capped the neighboring continent. Hawaii itself seems to have borne at least one small glacier, the characteristic traces of which were observed by the writer on Mauna Kea at the 12,000-foot level. The supposition that the present Hawaiian reefs began their growth in the post-Glacial interval is corroborated by the fact of their small size; they have evidently been growing but a short time.

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* E. Suess, The Face of the Earth, trans. by H. B. C. Sollas, vol. iv, 1909. p. 327.

† T. C. Chamberlin and R. D. Salisbury, Geology, vol. iii, 1906, p. 420.

‡ H. Hess, Die Gletscher, Braunschweig, 1904, p. 398; T. C. Chamberlin and R. D. Salisbury, Geology, vol. iii, p. 327, 1906; A. Penck, Morphologie der Erdoberflaeche, vol. ii, pp. 528, 660, 1894.

The latter statement may also be made concerning the majority of the coral reefs of the globe.

Is it not fair to believe that the reef corals were confined, during the Glacial period, to very limited areas, where prolonged winter cold did not surpass 20° C.? The reef corals were, of course, not exterminated during the Pleistocene, but they may well have been restricted to such warm, more or less enclosed seas as those of the East Indian region.

The imagination suffers, therefore, no painful stretch in our considering that, throughout the Glacial period, extensive marine abrasion in the equatorial belt was possible because of a general lack of growing coral reefs in the open ocean. The undefended islands, largely composed of relatively weak volcanic and calcareous materials, must, under the conditions, yield extensively to the waves, which as a rule ran in from very deep water on every side and thus, with special power, attacked the islands.

All competent observers agree that most of the atoll-forming reefs are founded on denuded volcanoes. Judging by the analogies found in Hawaii, Samoa, Fiji, etc., a large proportion of these truncated volcanoes, in their subaerial portions, were composed of massive lavas as well as of very much weaker ash and tuff deposits. To reduce such masses, wave erosion would demand vastly more time than is represented in the Glacial period. But there is no reason to doubt that the volcanoes here considered are of many different ages, possibly from the pre-Cambrian to the Tertiary. For the older ones, subaerial denudation must have gone still further than it has in greatly dissected islands, like Kauai, Tahiti, etc., and thus approached or reached peneplanation of the islands. Such denudation, combined with marine erosion during pre-Pleistocene time, had reduced most of the volcanic masses to the plateau form. As the recently elevated islands so often show, many of these platforms became veneered with, and flanked by, Tertiary limestone, and doubtless they were often capped by coral reefs of much greater total area than that of the existing coral reefs.

The Pleistocene islands, emerging because of the negative movement of sea-level, were, therefore, generally low (under 300 feet* in height), and, above the new sea-level, were composed largely of weak material. Exposed on all sides to abrasion by the open ocean, we may safely assume that these islands would lose substance at least as fast as the 300-foot chalk cliffs of Dover, namely, at the average rate of 3 feet 6 inches a year. At that rate, the Chagos Bank, by far the most extensive of the plateaus here considered (sixty miles by ninety miles), could have been reduced to the Pleistocene sea-level in about 50,000 years. The whole duration of nearly maximum glaciation in the Pleistocene was, as we have seen, much longer than that. The estimate allows nothing for that fraction of the Chagos plateau which is due to off-shore deposition during the abrasion; but this process, complementary to the abrasion, obviously explains a notable part of each plateau area.

We may conclude that marine erosion, under Pleistocene conditions, was amply competent to reduce most of the Tertiary thalassic islands to a low Pleistocene sea-level (see cols. 3, 4, and 5 of table). The same is true of the Australian continental shelf and of the similar shelves of New Guinea, Fiji, etc. Though the Australian shelf reaches 100 miles in width and was exposed to erosion on only one side, a large part of it must have been composed of weak sediments; these were rapidly benched by the Pleistocene breakers.

On the other hand, the lava-formed islands of late-Tertiary or Pleistocene dates, like Hawaii, Tahiti, Savaii, Murea, Bora Bora, and Huaheine, would stoutly resist abrasion. Their benches are, accordingly, not more than about two miles in width.

Growth of the existing Reefs.—The melting of the huge ice-caps must have been a slow process. They began to dissipate, doubtless through a general amelioration of climate. We may believe that the new platforms were colonized by reef-building species quite early in the melting stage and before the rising sea-level meant water of more than twenty fathoms, that is, water too deep for most reef-building species. Though we do not know precisely the average rate of growth on coral reefs, we do know that it is, geologically speaking, very rapid. There would seem to be no difficulty in assuming the rate as quite sufficient to keep the living zones of the reefs well within the 20-fathom isobath of the deepening ocean. The mechanism of growth, with the resulting development of atoll, barrier, and fringing reef forms, would be analogous to that imagined by Darwin and Dana on the subsidence hypothesis, though by the present writer's hypothesis most of the lagoons would tend to enlarge, rather than diminish in area, with the process of time.

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* This figure chosen on the assumption that the Antarctic and Greenland ice-caps were, perhaps, first formed in Quaternary time.

Drowned Valleys of Oceanic Islands.—The Pleistocene deepening of the inter-tropical seas is precisely of the amount required to explain the drowned valleys of the volcanic islands which are now surrounded by barrier reefs. The following list is representative of the maximum depths recorded for the drowned portions of these valleys:

	Maximum depth charted in valley (fathoms)
Tahaa, Society Islands	22
Raiatea, " "	19
Murea, " "	26–41
Huaheine, " "	25
Vavau, Tonga archipelago (two valleys, each)	30
Mbengha, Fiji group	19
Moala, " "	16

The maximum depth charted for these drowned portions of the valleys appears never to exceed 45 fathoms.

Dana's contention that the drowned valleys indicate crustal subsidence evidently needs revision, since a recent swelling of the equatorial waters without crustal movement gives the same result. By the hypothesis here suggested, these valleys must have been deepened during the time of heavy glaciation, when their base-level was lower than now and that for a total time long enough for the deepening of each valley to the extent required by the hypothesis.

Composite Atolls of the Maldives.—Late Pleistocene drowning will account for the existence of the many small atolls or "faros"[*] which make up the emerged rims of the great atolls of the Maldive archipelago. The typical form and relation of each "faro" to its main atoll fail of explanation on the Darwin-Dana hypothesis. Neither can the lagoon of the main atoll nor that of the bordering "faro" be explained by the doctrine of an unvarying sea-level. A study of the charts of the Maldives shows that Murray's hypothesis of solution by sea-water can hardly account for these lagoon basins. It may be recalled that, at Funafuti, the lagoon water is not sensibly richer in carbon dioxide (the special solvent invoked by Murray) than is the water of the open ocean; and, secondly, that the observers on Funafuti have decided that its lagoon is being slowly filled with shells, skeletons, and detritus, and is not increasing in depth through solution.

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[*] Cf. A. Agassiz, Memoirs Museum of Comp. Zoology at Harvard College, vol. xxix, 1903, p. xii.

But, granting: (1) a very slow rise of sea-level during the late Pleistocene, (2) an early colonization of the Maldive platforms, and (3) lateral growth of a reef at a rate much faster than the drowning (a most probable assumption): we can imagine a late Pleistocene coral patch soon spreading "like a fairy ring" to the size and shape of a "faro" atoll. That the "faros" are concentrated on the edges of the platforms is a natural and well recognized effect of the conditions of coral growth.

Summary of Conclusions.—A statement of the view that most atolls and barrier reefs were formed during a period of relative crustal repose is not complete until the effect of the Pleistocene lowering and subsequent swelling of the equatorial waters is considered. Since the positive movement of sea-level was not general, being offset in higher latitudes by the annulment of glacial attraction, the effect in the intertropical seas may be described as a heaping or *tumular* movement of water above the antecedent geoidal surface. To that tumular movement the peculiar forms and relations of atolls and barrier reefs are directly attributed. This idea obviously in no sense excludes complications due to local warpings of the earth's crust, with, for example, negative movement of sea-level in Fiji and positive movement at the Great Chagos Bank. The changes in sea-level due to glaciation and subsequent deglaciation have been discussed as though other processes had not affected general sea-level. They have been so far neglected in the argument because of the high probability that neither basin-foundering, nor sedimentation, nor absorption of water by weathering rocks seem to have been important enough, since the Tertiary, to affect, by more than a fathom or two, the changes of level assumed.

The related view, that most of the great plateaus now bearing atolls and barrier reefs were finally truncated by Pleistocene marine erosion, explains the remarkable flatness of these platforms and their nearly uniform depth of 45 to 50 fathoms. As Suess points out, these features can hardly be explained, either on the Darwin-Dana hypothesis or on Murray's hypothesis of solution inside the reef. Murray's conception, that many of the plateaus have been built up by calcareous accumulations on volcanic peaks which, by eruptions, had reached to depths within a few hundred fathoms of the surface, is in ill adjustment with his solution hypothesis. In any case it cannot solve the problem for the vast majority of reef-bearing plateaus.

Since reef-building corals doubtless flourished in the equatorial seas during the Tertiary period, and there greatly protected island and mainland from wave attack, the development of the smooth floors, on which the existing reefs stand, is not to be ascribed to Tertiary marine erosion. In fact, it is an open question whether the atoll archipelagoes do not represent a highly exceptional set of conditions, such as have very seldom prevailed in the history of the globe. According to the hypothesis here proposed, the essential conditions have included a hollowing (negative) movement of sea-level with subsequent heaping (positive) movement of sea-level, each movement being connected with that rare phenomenon, general glaciation. Atoll-forming periods may have been at least as rare as periods of such glaciation, and it is possible that only since the late Pleistocene has the first atoll archipelago come into existence. Single small atolls might have been formed at any time since the reef-building corals were evolved, but such groups of atolls as the Maldives, with their peculiar relation to the underlying plateaus, seem to demand special shifts of level. For explanation of existing atolls and barriers the preference is here given to a moderate tumular movement of the ocean, rather than to the enormous crustal displacements implied in the Darwin-Dana hypothesis. Correlating ice-caps and coral reefs, we use the great discovery of Louis Agassiz to support a principal conclusion of Alexander Agassiz. To the father, a zoologist, geology owes the glacial theory; to the son, a zoologist, geology owes a matchless collection of facts, which not only illuminate the theory of coral reefs, but also profoundly affect the problem of crustal deformation in the oceanic areas.

ART. XXXIII.—*The Probable Identity of Podolite with Dahllite;* by WALDEMAR T. SCHALLER.

A COMPARISON of the properties and chemical composition of podolite and dahllite shows them to be essentially identical. Dahllite was described in 1888 by Brögger and Bäckström,[*] and a description of it is given in Dana's System of Mineralogy, p. 866. Podolite was described by Tschirwinsky[†] in 1907, and the summary of the properties of the two minerals given below has been prepared from the printed descriptions.

Dahllite	Podolite
Occurs in crusts with fibrous structure, on apatite.	Occurs in crystalline masses or in prismatic crystals on phosphorite, also in spherulites of prismatic crystals.
Density is 3·053.	Density is 3·077.
Color is pale yellowish white.	Color is yellowish.
Uniaxial, negative.	Apparently hexagonal, crystals show optical anomalies, negative.
Double refraction and index of refraction slightly greater than that of apatite.	Double refraction somewhat greater than that of apatite. Mean index of refraction 1·635.
Soluble in cold dilute acid with evol. of CO_2.	Soluble in HCl with evol. of CO_2.
Composition: $H_2Ca_{14}P_8C_2O_{39}$ or $2Ca_3P_2O_8.CaCO_3.\frac{1}{2}H_2O$ See below.	Composition: $Ca_{10}P_6CO_{27}$ or $3Ca_3P_2O_8.CaCO_3$ See below.

To better compare the two formulæ, they are given below with Ca given in constant amount.

Dahllite.......... $H_{10}Ca_{70}P_{40}C_{10}O_{196}$
Podolite........... $Ca_{70}P_{42}C_7O_{189}$

The analyses of the two minerals are shown in the following table for comparison :

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[*] Brögger, W. C. and Bäckstrom, H. Dahllite, a new mineral from Odegården. Bamle, Norway, Meddelanden från Stockholms Högskola. No. 77 in Öfr. Vet. Akad. Förh., 1888, p. 493. Abstracted in Zeit. Kryst. Min., vol. xvii, p. 426. 1890.

[†] W. Tschirwinsky. Podolite, a new Mineral, Centr. Min. Geol. Pal., 1907, p. 279. For some earlier but incomplete descriptions in Russian publication, see abstract thereof in Zeit. Kryst. Min., vol. xlvi, p. 296.

Analyses.

	Dahllite	Podolite (crystals)	Podolite (crystalline aggregate)
CaO	53·00	51·15	51·31
P_2O_5	38·44	39·04	36·44
CO_2	6·29	3·90	4·18
H_2O	1·37	not det.	not det.
Fe_2O_3	0·79(FeO)	3·04	1·73
Al_2O_3	----	----	0·46
K_2O	0·11	----	0·45
Na_2O	0·89	----	0·66
F	----	0·00	0·26
Organic	----	----	0·56
SiO_2	----	----	4·87
	100·89	97·13	100·92 (—0·08 O for F).

The above figures confirm the idea of the identity of the three substances analyzed. The CO_2 values for podolite are somewhat lower than that given for dahllite, but the differences are slight. Water was not determined, but it undoubtedly would be present in such a secondary mineral as podolite, and, moreover, a small amount must have been absorbed by the sample during its pulverization. The poor summations and the varying values in general for podolite lead one to suspect that further analyses of purer material, carefully made, would lead to slightly different results from those here given.

It is hardly possible, from the data at hand, to determine what is the correct formula for this interesting phosphate and carbonate of calcium. A formula analogous to apatite seems to be suggested by the evidence, and the 1·37 per cent of water given in the dahllite analysis can be explained by other means than that it is essential to the mineral, but the question as to the presence of essential water can only be settled by further analyses made with due consideration of all the influencing conditions. The name dahllite has priority over podolite by nearly twenty years, and the latter should, therefore, give way to the older name. What relation staffelite bears on these minerals can hardly be settled at this time, as the properties of staffelite are but poorly characterized.

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Art. XXXIV.—*The Identity of Stelznerite with Antlerite*; by Waldemar T. Schaller.

Stelznerite was described as a basic copper sulphate by Arzruni and Thaddéeff* in 1899, their paper being edited by A. Dannenberg on account of the death of Arzruni. Prof. F. W. Clarke has recently called my attention to the chemical identity of stelznerite with a mineral analyzed by Dr. W. F. Hillebrand and named antlerite.† I have extended the investigation by examining optically some of the original type material of antlerite in the U. S. National Museum, for which privilege I would acknowledge the kindness of the Assistant Curator, Dr. J. E. Pogue. All the facts obtained point to the identity of stelznerite with antlerite.

On examining antlerite under the microscope it was seen to consist of a homogeneous aggregate of very minute crystals of a short prismatic habit and of a pale greenish color. The crystals extinguished parallel, but were too small for any determination of their optical orientation. The small crystals were not perceptibly pleochroic, but on the thicker ones a decided pleochroism was noticed, identical with that described for stelznerite. Parallel to the elongation of the crystals, the color was blue-green; normal thereto the color was yellow-green. The double refraction was high. These data are all in accord with those given for stelznerite. The values of the density, 3·93 (antlerite) and 3·884 (stelznerite, not corrected for admixed gypsum), agree closely.

Chemically, the two minerals are also seen to be identical, as first noted by Professor Clarke. The formula deduced for stelznerite is $3CuO.1SO_3.2H_2O$ or $CuSO_4.2Cu(OH)_2$, while Hillebrand calculated the more complex one, $10CuO.3SO_3.7H_2O$ or $3CuSO_4 + 7Cu(OH)_2$ for antlerite. The analyses of antlerite are compared with those of stelznerite in the table below. Nos. 1 and 2 are Hillebrand's analyses of antlerite, with 8 and 6 per cent, respectively, of gangue deducted, and Nos. 3 and 4 are the analyses of stelznerite. No. 5 gives the calculated composition for the formula $3CuO.1SO_3 2H_2O$, while No. 6 gives that for the more complicated formula $10CuO.3SO_3.7H_2O$.

Though the first analysis of antlerite agrees better with the more complex formula, the second analysis agrees nearly as well

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* Arzruni, A. and Thaddéeff, K. Neue Minerale aus Chile, etc., Stelznerit, ein neues basisches Kupfersulfat. Zeit. Kryst. Min., vol. xxxi, p. 229, 1899.

† Hillebrand, W. F. Mineralogical Notes (6. A Basic Cupric Sulphate), Bull. U. S. Geol. Survey, No. 55, p. 48, 54, 1889. Also given in Dana's System of Mineralogy, 6th ed., p. 928.

	Antlerite		Stelznerite		Calculated $3CuO.1SO_3.2H_2O$	Calculated $10CuO.3SO_3.7H_2O$
	1	2	3	4	5	6
CuO ...	68·19	67·64	67·08	64·01	67·22	68·45
SO_3	20·46	21·49	22·40	22·19	22·61	20·69
H_2O....	11·11	10·76	10·22	10·37	10·17	10·86
ZnO ...	0·29	0·04	....	....	....	....
CaO ...	0·05	0·04	0·06	0·57	....	....
Fe_2O_3 ..	....	....	0·34	1·14	....	....
Residue.	....	....	0·44	1·42	....	....
Moisture	....	....	....	·33	....	....
	100·10	99·97	100·54	100·03	100·00	100·00

with the simpler stelznerite formula. As no certain differences could be found in the optical properties and as the analyses agree so closely with one another, the two minerals stelznerite and antlerite must be considered as identical.

The characterization given stelznerite is much more complete than that of antlerite, and the formula deduced, $CuSO_4.2Cu(OH)_2$, is also simpler and is doubtless the correct one for the species. The name antlerite has, however, priority by ten years, and is the one to be adopted.

On careful investigation antlerite will doubtless be found to be much more abundant than is now thought, and much of what is now called brochantite may be found, on analysis, to be the closely related antlerite. Thus the artificial brochantite, described by Dana on page 926 of the System of Mineralogy, is in reality antlerite.

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ART. XXXV.—*On the Electromagnetic Emission Theory of Light;* by JACOB KUNZ.

§ 1. *General considerations.*

THE problem of the nature of light is again a prominent one in theoretical and experimental investigations. Since Huygens, the wave theory of light has been found in such a perfect agreement with the phenomena that the older emission theory has been given up. Through Maxwell, the wave theory, so far based on an ether with elastic properties, has been given an electromagnetic interpretation, and a new field of phenomena, the electrical oscillations discovered by Hertz, bridged over the gap between electrical and optical phenomena. While the electromagnetic wave theory of light accounted for the groups of phenomena of reflection, refraction, interference, polarization, etc., difficulties were found in the explanation of the aberration, and of the experiments of Airy, Fizeau and Michelson-Morley. These phenomena, apparently contradicting themselves, have finally been interpreted from the standpoint of the principle of relativity. This principle tells us that the equations by means of which the laws of nature are expressed remain the same no matter whether the system of coördinates to which they are related is in motion or at rest. If this be so, then we are free to coördinate "ether" to the system of coördinates at rest or to the system in motion; in other words, we may picture to ourselves the ether at rest with respect to the system of coördinates in motion or with respect to the coördinates at rest. It appears superfluous and arbitrary to introduce an independent medium like ether in our electromagnetic theories. Thus the principle of relativity rejects the ether. On the other hand, energy of radiation appears to be materialized or inseparably connected with mass.

$$dE = dmc^2$$

The principle of relativity, giving up ether, points towards elements of electromagnetic energy, that have a certain analogy with material particles.

Independent of the principle of relativity, the theory of radiation of the black body has been developed by Lorentz, Planck, Larmor, J. J. Thomson and others. For long wave lengths the different ways of attacking the problem lead to exactly the same law,

$$dE = \frac{CT}{\lambda^4} d\lambda$$

but for the general law of radiation, and especially for short wave lengths, considerable difficulties have been encountered by every investigator. Planck in the theory of radiation assumes that the resonators gain or lose energy, not quite gradually by infinitely small amounts, but only by certain portions of a definite finite magnitude. The portions of energy depend on the frequency n of the resonator, so that

$$E = hn.$$

Planck's law shows a remarkable agreement with the experimental results and allows the determination of the fundamental quantities of nature; yet the mechanism of radiation is not revealed by the theory; it seems to me, that the resonators have but little analogy with the motions of the electrons in metals, which lead us to assume a connection between Röntgen rays and light. Moreover as far as our present knowledge goes, we have no experimental evidence of portions of electromagnetic energy of the form hn; the experiments made on the photoelectric effect of sodium-potassium alloy, made by the author, show that the kinetic energy of the electrons emitted by this alloy is for a considerable range proportional to the square of the frequency of the incident light. On the other hand, it is well known that the optical properties of metals cannot be deduced quantitatively with any degree of accuracy from the electrical properties. It has been shown, however, by Hagen and Rubens that rays of light of wave length between 8 and 25 μ are absorbed to a degree that may be calculated with considerable accuracy from the conductivity.

H. A. Lorentz has based a theory of thermal radiation on this fact, which, however, is restricted to long wave lengths and coincides with the formula given above. This theory has been extended to short waves by J. J. Thomson, and I have shown what would be the acceleration of the electron in the case of collision with an atom. I came also to the conclusion that the energy of a monochromatic beam of light is proportional to the square of the frequency, a result which seems to agree with the present experiments.

Whereas the principle of relativity and the theory of radiation of Planck assume discontinuities in the emission and absorption of light, there are many optical phenomena pointing towards a corpuscular constitution of light and Röntgen rays. This is so much so, that a special corpuscular theory of Röntgen rays has been developed by Bragg, who considers them as made up of doublets of positive and negative particles. The main facts in the line of his argument are as follows: The number of atoms in a gas ionized by Röntgen rays is exceedingly small, while we should expect that all the atoms struck by Röntgen rays in which the energy is distributed uniformly over the wave front, suffer the same change. When Röntgen rays pass through a region in which there are free electrons, they tend to make the electrons move in the same direction as those which produced the rays; in addition, the velocity of the electrons emitted from the metals under the action of Röntgen rays is about as high as the velocity of the primary electrons which produced the Röntgen beams; the number of electrons in the photoelectric effect depends only on the intensity of the light, not on the color, while their velocity depends only on the color and not on the intensity;—phenomena that we should expect from the point of view of an emission theory.

Thus without considering the emission of spectral lines and the phenomena of phosphorescence, we have a certain number of independent theories assuming a discontinuity in the emission of light, and a certain number of phenomena which have not yet been explained on the ground of the ordinary undulatory theory of light.

That theory will finally succeed in the explanation of the optical phenomena which is able to combine all experimental facts under one and the same point of view; the question then arises, which of the present theories may in the future be able to give the key to the secret of the mechanism of the phenomena of light?

Considering the wave theory and its electromagnetic interpretation by Maxwell as well established, we can only expect a very slight change in these theories as possible and compatible with the explanation of some new phenomena not yet explained. It seems to me as if the Faraday–Thomson conception of electrical forces or Faraday tubes may ultimately lead to a satisfactory theory of light. Sir J. J. Thomson,* following the idea of Faraday, ascribes to the lines of electrical force a certain physical reality, the tubes of force being endowed with mass, momentum and energy. In the paper mentioned above, J. J. Thomson considers the properties of the field if the electric force due to an electron is exerted in only one direction. It appears that the mass of the electron considered as a function of the velocity varies in the same way as is required by the principles of relativity. There are other ways of reasoning which lead to the same result, so that even if the formula

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

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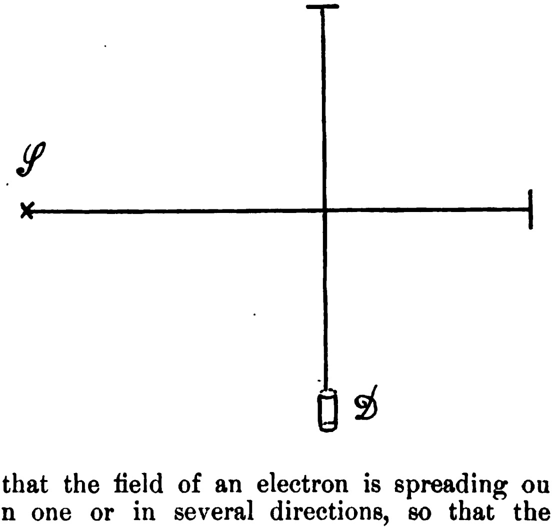
* Sir J. J. Thomson: On the Theory of the Structure of the Electric Field and Its Application to Röntgen Radiation and to Light. Phil. Mag., xix, p. 301, 1910.

should be confirmed by experiment, we could hardly consider the result as a demonstration of the principle of relativity. The radius of an electron carrying a tube of force in one direction is much larger than the radius calculated on the assumption of a uniform distribution of the electric field around the electron. The effects produced when a moving electron is suddenly brought to rest, or when its motion is accelerated, are very similar to those calculated on the usual assumptions.

Of course, it is possible that there are a very large though finite number of Faraday tubes attached to the electrons, so that the electric field is finally little different from what we consider at present, and then we should in the limiting case have the same properties as we find in the usual electromagnetic wave theory of light. The great problem is to determine whether there is such a limit or a discontinuity in the space of an electric field. The theory of thermal radiation can be developed very nearly in the same way, as it is now, if we assume that the field of an electron is spreading out from a center in one or in several directions, so that the change involved in the present theory of radiation would be very slight.

Fig. 1.



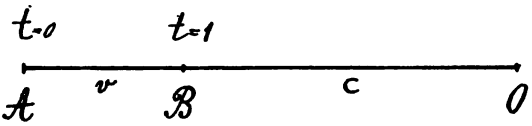
On the other hand, the explanation of the optical phenomena of aberration, of the Airy, Fizeau and Michelson-Morley experiment, would be very simple.

The theory under consideration makes an independent medium like ether unnecessary; it has features of the emission theory in common with the wave theory. The Faraday tubes when in motion carry electromagnetic mass, momentum and energy with them. The phenomenon of aberration is explained in the same way as any of those phenomena which usually are taken as illustration of the phenomenon; a gun at rest and a boat in motion, or the rain drops falling on the windows of a train in motion. The illustrations lend themselves indeed better for the electromagnetic emission theory than for the ether wave theory. Airy's and Fizeau's experiment need a more careful consideration, but they have never caused serious difficulties, and I shall try to give an elementary theory in this connection a little later.

§ 2. *Michelson-Morley experiment.*

As we are in this theory dealing only with relative motion between the source and the observer, the interference fringes observed through the telescope D will remain the same whatever may be the relation between the optical apparatus and the earth. In the Michelson-Morley experiment the relation between the source and the telescope remains unchanged; we can therefore expect no aberrational motion in the interference fringes. In this explanation no change of the units of time and space is required; and the explanation is very simple. But, on the other hand, the difficult question now arises as to the possibility of interference. The old emission theory of Newton cannot account for interference, but the electromagnetic emission theory, involving vibrating Faraday tubes connecting with the oscillating electron, seems to provide a means of explanation of interference. If the number of Faraday tubes connected with an electron were very large, we should expect the same phenomena of interference as in the wave theory. And if there were only two tubes attached to the electron, spreading out in opposite directions, J. J. Thomson points out that even in this case interference might be possible, because the vibrations along a considerable number of tubes coming from a luminous body must have their phases related in a definite way. A vibration from an electron will strike against other electrons and excite vibrations, which are in definite phase relations with the primary vibrations.

Fig. 2.



§ 3. *The Doppler effect.*

Let a source of light be moving with velocity v along a line AO, emitting disturbances of frequency n in all directions; the velocity of propagation will be equal to $c+v$; after one second the first disturbance emitted in A will reach the observer in O. If we start counting the time in the moment in which the source is in A, then in $t=1$ the source will be in B and emit the nth disturbance. This disturbance will reach the observer after a time $\tau=\frac{c}{c+v}$. Hence the observer receives n disturbances in the time interval $\frac{c}{c+v}$, or n' disturbances per unit time:

$$\frac{c}{c+v}:n=1:n'$$

$$\frac{n'}{n}=\left(\frac{c+v}{c}\right) \qquad \begin{aligned} n'\lambda' &= c+v \\ n\lambda &= c \end{aligned}$$

$$\frac{\lambda'}{\lambda}=\frac{c+v}{c}\cdot\frac{n}{n'}=1$$

or the wave length remains unchanged.

In the case of sound we have:

$$\frac{\Delta\lambda}{\lambda}=\frac{v}{c}$$

and this formula is also used in spectroscopy for the determination of the velocity of stars.

The principle of relativity leads to the expression:

$$\frac{n'}{n}=\frac{\sqrt{1-\frac{v^2}{c^2}}}{1-\frac{v}{c}} \qquad n'\lambda'=n\lambda$$

while the emission theory here sketched gives the result:

$$\frac{n'}{n}=\frac{c+v}{c}$$

On the other hand, the principle of relativity maintains that the velocity of light is always the same, c, whatever be the velocity of the source or of the observer. The electromagnetic emission theory holds that the velocity of light given out by a source of light in motion varies with the direction of propagation of light. In the direction in which the source of light is moving, the velocity of light is equal to $c + v$, in the opposite direction equal to $c - v$, in the perpendicular direction, c.

The experiment should be able to decide between these alternative theories. Among different possibilities the canal rays lend themselves perhaps in the first place to an experimentum crucis. We are here dealing with positive particles whose velocity in hydrogen may be as high as 10^8 cm./sec., or only 300 times smaller than the critical velocity, c, of light. If it could be shown that the velocity of light given out by those moving particles is the sum $c + v$, the principle of relativity would disappear and the electromagnetic emission theory would be victorious. If the velocity of these positive particles was found to be c in all directions, the emission theory would have to disappear forever.

The velocity of the source of light in the canal rays determined by means of the Doppler effect varies from 30–80 per cent of the velocity computed from the cathode fall of potential and the value e/m. A simultaneous determination of the velocity of canal rays by means of the Doppler effect and by means of the electrostatic and electromagnetic deflection would be very desirable.

§ 4. *Interference.*

The emission theory suggests the possibility of a difference in the interference of two beams issuing under a large angle from the same source and the interference due to two beams issuing in the same or very nearly the same direction. The light from two sources is not susceptible of interference, while interference occurs in a beam from one source, because there are phase relations between the oscillations in the Faraday tubes, issuing from one source. It may be that for this reason N. Campbell* has not yet succeeded in searching after a difference in the "events" of the photoelectric effect, due to two beams separated by interference.

If, however, the energy travels out from the source along certain directions, we should finally be able to detect, for instance in the case of Röntgen rays, a scintillation effect, or at least discontinuities in the phosphorescence of a sensitive screen. It is possible, too, that one screen could show such discontinuities while another does not, because if a molecule is made a source of light, it might affect the neighboring molecules to emit light also; and in this way a discontinuity, originally present, might be masked. Perhaps the idea of

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* N. Campbell, Discontinuities in Light Emission. Proceedings of the Cambridge Philosophical Society, vol. xv, p. 310, 1909.

Campbell's experiment might be tested by means of a Röntgen bulb rather than by a source of light. At all events, there are two important facts which show that if the phenomena of light can be explained by an emission theory, the neighboring trains of oscillations issuing from a source of light must be in a very close phase relation. The path difference between two beams that can interfere with each other can amount to over 100,000 waves and the light, susceptible of interference, may be exceedingly weak. If light or Röntgen rays were able to produce mechanical effects, for instance to disintegrate metals, then the velocity of the particles emitted ought to be independent of the intensity of the light, and the quantity of disintegrated product ought to be proportional to the quantity of light.

§ 5. *Photochemistry.*

A great field of optical phenomena, including the photographic processes, are still awaiting explanation. The fundamental law of the photochemical action could be deduced at once from the electromagnetic emission theory of light. The photochemical action is the same when the product of time and intensity of the incident light remains the same. Exactly the same law holds in the photoelectric effect; the number of electrons emitted from a metal plate under the action of light and Röntgen rays depends only on the quantity of light impinging. These laws are of the same type as Faraday's law of electrolysis. And as in the photoelectric effect and in the ionization of gases the number of electrons or ions is only very small, so also is the number of molecules by exposing a photographic plate to light exceedingly small, whereas from the wave theory, where the electromagnetic energy is distributed uniformly over the wave-front, we should expect that all molecules should behave in the same way.

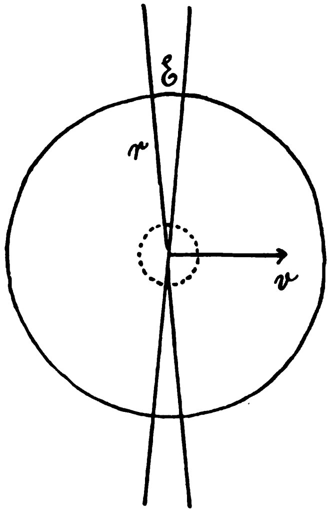
The velocity of the photochemical reactions does hardly depend upon the temperature; the ionization of gases also is independent of temperature; the mechanism of these phenomena appears to be of the same nature.

Now the electrical force in a sunbeam is about 10 volts per centimeter and about 0·5 volts per centimeter in the pulse of the Röntgen rays, while the electrical force required to drag an electron out of an atom of gas is about $2 \cdot 10^{9}$ volts per centimeter, corresponding to the work necessary to produce an ion, which is equal to $4{,}410^{-11}$ ergs. It is as a rule said, that the ionization of gases, the photoelectric effect and some of the photochemical reactions are due to resonance processes; but it can be shown that it would require several minutes before ultra-violet light could produce an ion in this way and it would require about 200 days of action of Röntgen rays before one single ion could be formed. Resonance on the ground of the continuous ether theory does not account for ionization. That a considerable amount of work is also required to drag an electron out of a metal follows from a recent investigation of the spark discharge by W. W. Williams, who found no spark in a distance of 1,5λ of sodium light when the potential difference was as high as 300 volts.

§ 6. *The intrinsic magnetic field of ferromagnetic substances.*

The hypothesis of the intrinsic or molecular magnetic field due to P. Weiss has thrown a good deal of light on the magnetic properties of the ferromagnetic substances. The molecular field accounts for the very high value of the magnetization of iron, nickel and cobalt. There are some discrepancies between theory and experimental results; for instance, is the law of approach of the intensity of magnetization to saturation not that required by theory, except for cobalt and the variation of the intensity of magnetization with the temperature at very low degrees, does not quite follow the curve given by theory.

FIG. 3.



This fact is connected with another result of recent investigation on magnetism, showing that the paramagnetic susceptibility is not in general inversely proportional to the absolute temperature, as was assumed by Curie and Langevin, who considered therefore the moment of an elementary magnet as independent of the temperature. These results make a certain modification of the theory necessary, but in the main features the agreement between the theory and the experimental results is so close that the hypothesis has at least the value of a working hypothesis. It has been shown by the author of this article* that the theory allows us to determine the absolute values of the moments of the elementary magnets of iron, nickel and magnetite, and that we can determine in this way the elementary quantity of electricity; the value e obtained in this way agrees well with that given by Rutherford.

While the moment of the elementary magnet can be accounted for by the usual electron theory, it seems almost impossible to account for values of the molecular field as high as 6,560,000 absolute units in iron and 14,300,000 in magnetite.

For if we assume the frequency n of an electron equal to that of sodium light $n = \frac{1}{2}\, 10^{15}$, the velocity of the electron revolving in a circle would be equal to

$$v = 2\pi n r$$

where r is the radius of the orbit of the electron which we shall assume to be of the order of magnitude $10^{-8\ \mathrm{cm}}$

$$v = 3,\, 14 \cdot 10^{7\ \mathrm{cm}}$$

The electric force at E is equal to $\frac{e}{r^2}$ under the usual assumption of uniform distribution of the Faraday tubes around the electron $E = \frac{1,55 \cdot 10^{-20}}{10^{-16}} = 1,55 \cdot 10^{-4}$.

If we now assume that the tubes spread out in the form of narrow cones in only two directions so that the part of the surface of the sphere cut out by the cones is 1/1000 of the whole surface, then the electric force in E will be 1000 times larger than before, assuming that the properties of the isolated tubes are the same as those possessed by a tube forming part of the continuous electric field. $E = 1,55 \cdot 10^{-1}$. If now the tube is moving, there is a magnetic force acting at each point in the tube, the direction of the magnetic force being at right angles to the plane containing the electric force and the direction of the motion of the tube at the point, the magnitude of the magnetic force being the product of the electric force and the component of the velocity at right angles to this force. If the angle is equal to 90°, the magnetic force H will be equal to

$$H = E.v = 3,14 \cdot 10^7 .\ 1,55 \cdot 10^{-1}$$
$$= 4,9 \cdot 10^6 \text{ absolute units.}$$

In this way it would be easy to account for the very high values of the molecular field of the ferromagnetic substances.

Laboratory of Physics, University of Illinois,
Urbana, July 14, 1910.

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* J. Kunz: The Absolute Values of the Moments of the Elementary Magnets of Iron, etc. Physical Review, vol. xxx, p. 359, 1910.

Art. XXXVI.—*Some Apparent Variations of the Vertical observed at the Cheltenham Magnetic Observatory*;* by John E. Burbank.

This paper deals with some slow period changes of level of the piers on which the Omori horizontal pendulum seismograph has been mounted at the Cheltenham Magnetic Observatory.

From November, 1904, to October, 1907, both components were mounted on stone piers in the north room of the variation observatory.† In October, 1907, the entire instrument was moved to a new location and mounted on a massive concrete pier.‡ A comparison of the diurnal oscillation of level and also the changes of level due to temperature variations, in the two places, shows that the magnitude and direction of these effects are to a large extent local.

The diurnal oscillation of level has been noted at many seismological stations. Professor J. Milne§ has studied this effect in Japan and elsewhere and has observed it in the soil 12 feet below ground level, but did not observe it when the instrument was mounted on the solid rock in a cave. He found the diurnal wave hardly appreciable in a wood where the trees protected the pendulum house from the direct effects of the sun. At all stations where the ground was covered with trees or buildings more upon one side of the station than upon the other, the diurnal waves were large, and often differed in phase. At most stations on wet and cloudy days diurnal waves were absent.

E. von Rebeur-Paschwitz‖ compared the diurnal oscillation of the surface of the ground at three places—Wilhelmshaven, Potsdam, and Puerto Orotavo, Teneriffe; he found the effect most pronounced in the east-west direction, and comparatively small in the north-south direction.

At Wilhelmshaven the pier was erected in the cellar of the Naval Observatory, the surface of the ground is marshy, with a layer of 2 to 3 meters of clay, and below this sand to a great depth.

At Potsdam the pier was mounted in the cellar below the east tower of the Astrophysical Observatory, the soil being sand to a great depth.

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* Communicated by permission of the Superintendent U. S. Coast and Geodetic Survey. Read before the Philosophical Society of Washington, Jan. 29, 1910.

† For description of the Observatory see Appendix No. 5, Report of the Superintendent U. S. Coast and Geodetic Survey, 1902; also Terrestrial Magnetism, vol. viii, pp. 11–30, March, 1903.

‡ See Terrestrial Magnetism, vol. xiii, pp. 1–20, March, 1908.

§ J. Milne, Movements of the Earth's Crust, Geographical Journal, vol. vii, p. 229, March, 1896.

‖ See reprint in British Association Report, 1893.

At Puerto Orotavo the seismograph was mounted at ground level on the cement floor of a small building on the side of Pico de Teyde about 18 kilometers from the summit.

The diurnal range of oscillation of the plumbline (apparent variation of the vertical) at these three places agrees remarkably well with the ranges of those elements which are a measure of the intensity of the solar radiations; the actual range differing, however, between the three places. The times of maximum east and west displacements also differ.

In fig. 2 are given curves for the diurnal oscillation of the plumbline on clear days for the three places: (O) Puerto Orotavo, (P) Potsdam, and (W) Wilhelmshaven. Negative ordinates indicate motion of plumbline toward east, and positive ordinates motion toward west. An increase of temperature caused deviation toward the east in each case, the amount at Wilhelmshaven being far the largest of the three. Barometric variations caused tilting at Wilhelmshaven and Puerto Orotavo but not appreciable at Potsdam.

Dr. J. R. Sutton* found that the seismograph piers at Kimberley, S. Africa, showed a diurnal variation of level with a range of from about 2 seconds of arc in summer to about 4 seconds in winter. The maximum westerly elongation occurred about 5h. 30m. A. M., and the maximum easterly about 4h. 15m., the median positions a little before 11 A. M. and 9h. 30m. P. M.

Mr. B. M. Varney† studied the diurnal variation at Cambridge, Mass., and found that it occurred only on days when the sun shone. The E-W component showed a tilting toward the east during the forenoon, which died out about noon and was followed by a tilting toward the west during the afternoon. The N-S component showed a tilting toward the south during the forenoon, and to the north later in the day. It was much smaller than the E-W motion.

The existence of this diurnal oscillation of the level has been noted by Ehlert,‡ at Strassburg, at a depth of 5 meters below the surface; by Denison,§ at Victoria, B. C.; Lagrange, at Uccle‖; Claxton, at Mauritius,¶ and Wallis,** on the Milne seismograph, at Honolulu Magnetic Observatory. It has also been noted at Sitka, Alaska, at the Weather Bureau in Washington, and doubtless at nearly every seismological station in the world.* Dr. Hecker† states that it was not entirely eliminated at a depth of 25 meters below the surface at Potsdam.

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* Preliminary Note on the Diurnal Variation of Level at Kimberley, Transactions Royal Society of S. Africa, vol. i, pt. 1, pp. 303–309.

† Some Long-period Deviations of the Horizontal Pendulum at the Harvard Seismographic Station, Science, Feb. 11, 1910.

‡ Beiträge zur Geophysik, iv, p. 70.

§ The Effect of Atmospheric Pressure upon the Earth's Surface, Journal of the Royal Astronomical Society of Canada. Nov.-Dec., 1908.

‖ Périodicité Sismique Bulletin de la Société Belge d'Astronomie, July, 1904.

¶ Results of Mag. and Met. Observations made at Mauritius in 1906.

** Not yet published.

This diurnal oscillation of the surface of the ground appears to be a general effect which does not admit of easy explanation. It appears, however, in some cases to be largely conditioned by the immediate surroundings of the pier.

The seasonal and annual variation of level has been studied by Paschwitz, Denison, Wallis, Hecker, Klotz‡ and numerous others. The results for the stations on the continental areas appear irregular and are not easily explained.

An attempt to determine the annual range of level at this observatory shows that it is comparatively large, but the results are far from satisfactory. The screw which controls the lateral movement of the cylinder, spacing successive lines 3 millimeters apart, does not have uniform pitch and successive days' records are not always controlled by the same part of the screw. This error of the screw prevents a study of the long-period variations of level, but is not great enough to seriously affect results extending over a period of one or two weeks.

The possible effect of variations of atmospheric pressure on the change of level has been studied by von Rebeur Paschwitz,§ who noted at Wilhelmshaven a deviation of level of 0·29″ of arc for one millimeter variation of the barometer. This extraordinary fluctuation was attributed to the marshy, spongy nature of the ground. His later observations at Strassburg show that the effect of barometric variations there is uncertain.

Professor Omori describes three cases of remarkable tilting of the ground in Japan during storms. At Tokyo, on Oct. 10–11, 1904,‖ when an extreme oscillation of level amounting to 3·5 seconds of arc occurred in a few hours, and again on Jan. 10–11, 1906,¶ when the extreme range amounted to 2·87 seconds of arc, and at Mito, some distance northeast of Tokyo on March 23, 1907,** when a range of 3·7 seconds of arc occurred between 10 A. M. and 5 P. M. Professor Omori considers that these remarkable variations are in large part due to an abnormal rise of the sea under the storm center in excess of the amount necessary to compensate the barometric pressure.

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* The references in connection with this paper are very incomplete, as they include only the few which have come to my attention.

† Beobachtungen an Horizontalpendeln über die Deformation des Erdkörpers unter dem Einfluss von Sonne und Mond, Veroff. des Kgl. Preussischen Geodätischen Institutes, Neue Folge Nr. 32, 1907, 95 pages.

‡ Report Chief Astronomer (Canada), 1907. Appendix 2, Ottawa, 1908.

§ Berträge zur Geophysik, xi, p. 334.

‖ Publications of the Earthquake Investigation Committee, No. 21, pp. 5-8.

¶ Bulletin Imperial Earthquake Investigation Committee, vol. i, No. 4, August, 1907.

** Bulletin Imperial Earthquake Investigation Committee, vol. ii, No. 1, March, 1908.

This barometric effect has been studied in this country by Denison, Varney and Klotz. Denison's results at Victoria, B. C., extend over a period of 11 years and present some very interesting and valuable information.

In 1908 the records of the seismograph at this observatory for about two years previously were very carefully examined for indications of changes of level due to the passage of areas of high and low pressure across the eastern part of the United States and no satisfactory relation was observed.

The more or less pronounced variations during this period showed a fairly systematic agreement with the temperature changes accompanying the passage of these low or high areas. These temperature changes were often such as to cause a pronounced tilting away from the storm center (low) and at other times such as to cause an equally pronounced tilting toward the center of low pressure. The direction of the tilting did not change appreciably as the center advanced from west to east, except as the temperature changed.

While the barometric variations produce an effect which can be readily measured by sufficiently sensitive instruments, it is in many locations entirely obscured by changes of level due to causes of a local nature. This yielding of the earth's crust to variations of barometric pressure is discussed by Sir G. H. Darwin.*

A general formula for the tilting shown by a horizontal pendulum can be derived as follows: Let M be the steady mass at the end of the horizontal strut x, see fig 1. This strut ends at A in a hardened steel, cup and point bearing. The weight of M is supported chiefly by two guy wires, BM, attached at opposite sides of M, and joined, near B, in a yoke which terminates at B in a point and cup bearing, similar to that at A.

Let θ be the angle between AB and the vertical.

x distance A to M (center of mass of suspended system).

h vertical distance of B above horizontal plane through A.

Since x is usually horizontal and θ is always a very small angle, the distance x can be taken as the approximate length

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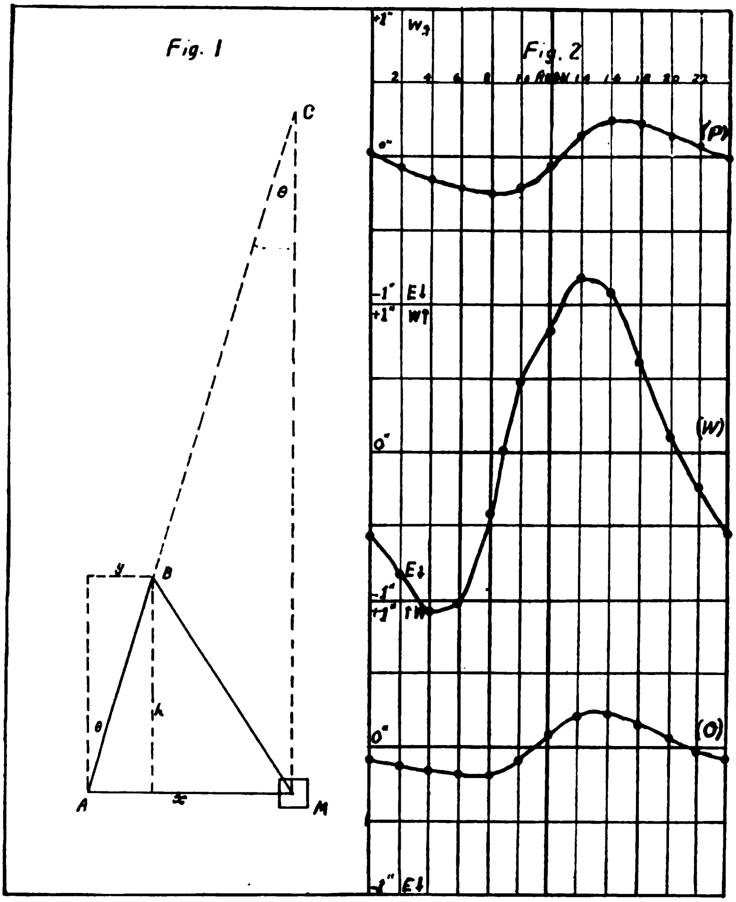
* Scientific Papers, vol. i, pp. 444–450; or Phil. Mag., vol. xiv, 1882, pp. 409–427; or British Association Report for 1882, pp. 106–119.

FIGS. 1, 2.



of the simple pendulum by placing AB horizontal. Let t be the period of the pendulum so placed.

The distance CM is the length of the equivalent simple pendulum, namely, one having the same period, T, as the horizontal pendulum.

$$(1) \qquad \operatorname{Sin} \theta = \frac{x}{\mathrm{CM}} = \frac{t^2}{\mathrm{T}^2}$$

From the measured value of x and the observed value of T, θ can be readily computed.

If the pier or pedestal be tilted in a plane normal to AM through the angle i, the center of mass, M, will move through the distance z to a new position of equilibrium. The displacement of M is the same as that of a simple pendulum of length CM supported on the same pier.

$$(2)\quad \text{Hence } \sin i = \frac{z}{\text{CM}} = \frac{4\pi^2 z}{g\text{T}^2}$$

$$(3)\quad \text{or}\qquad z = \frac{g}{4\pi^2}\,\text{T}\,\sin i.\quad\text{(Parabola.)}$$

For a given value of i, z varies directly as T.

If n be the multiplying ratio of the writing arm and z' the displacement on the record,

$$(4)\quad z' = nz = \frac{ng}{4}\,\text{T}^2 \sin i,\ (4)\text{ can also be written}$$

$$(5)\quad z' = xn \sin 1'' \frac{\text{T}^2}{t^2},\text{ which is the form used by Professor}$$

Omori.*

The pendulums used here have x about 75^{cms} and t about 1·74 seconds, and when T is 28 seconds and n equals 10 a change of 1″ in the level of the pier corresponds to a lateral displacement of 9 millimeters on the record sheet. The cylinder revolves once per hour, and also moves laterally at the rate of 3 millimeters per revolution, so that the pen traces a spiral, the lines under normal conditions being spaced 3 millimeters apart. Any tilting of the pier or pedestal in the line of free motion of the pendulum would produce a crowding together or separating of these lines. The amount of tilting during short intervals of time, say 3 or 4 days, can be quite accurately determined by measuring the excess or defect of the spacing over the normal amount, 3 millimeters per revolution.

A careful study of the records for the period Jan. 1906 to Oct. 1907 shows that the piers on which the two components were mounted were tilted by pronounced changes of temperature. These piers were exceptionally well protected against sudden changes of temperature, aud the building would further protect the ground around the piers from very sudden changes of temperature.

With gradual rise of temperature the top of the N-S pier tipped toward the north and top of the E-W pier toward the west. With falling temperature both sets of piers returned toward their normal positions.

A study of the diurnal tilting during Jan. 1906 to Oct. 1907 shows that it occurred on the E-W component on all clear days. This relation was so definite that it was possible to tell by the appearance of the record if the sun shone for a couple of hours during the day. No definite tilting could be observed on the N-S component. This may be due in part to the fact that the absolute observatory is placed directly south of the variation observatory, thus shading the ground on that side.

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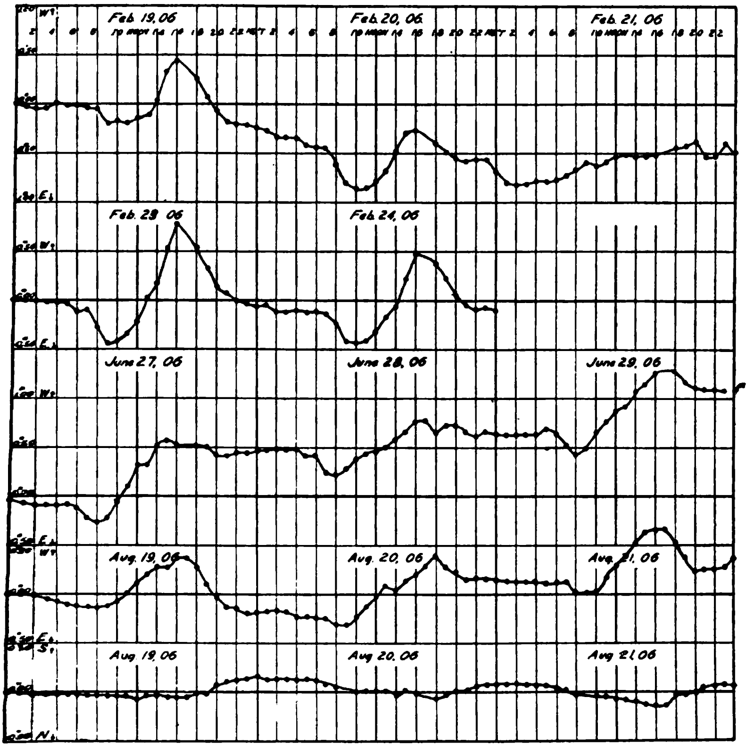
* Publications of the Earthquake Investigation Committee, No. 21, pp. 5–8.

In fig. 3 are shown a few curves of the E-W component from the records of the year 1906. The lowest curve is for

FIG. 3.



the N-S component and shows the inappreciable amount of tilting it experienced.

Of the eleven days for which curves are given, Feb. 21 was cloudy, Aug. 20 and 21 partly cloudy, and all others were clear.

In these curves a negative ordinate or motion downward indicates a movement of the top of the W-E pier toward the east and of the N-S pier toward the north; movements upward corresponding to tilting toward the west and south.

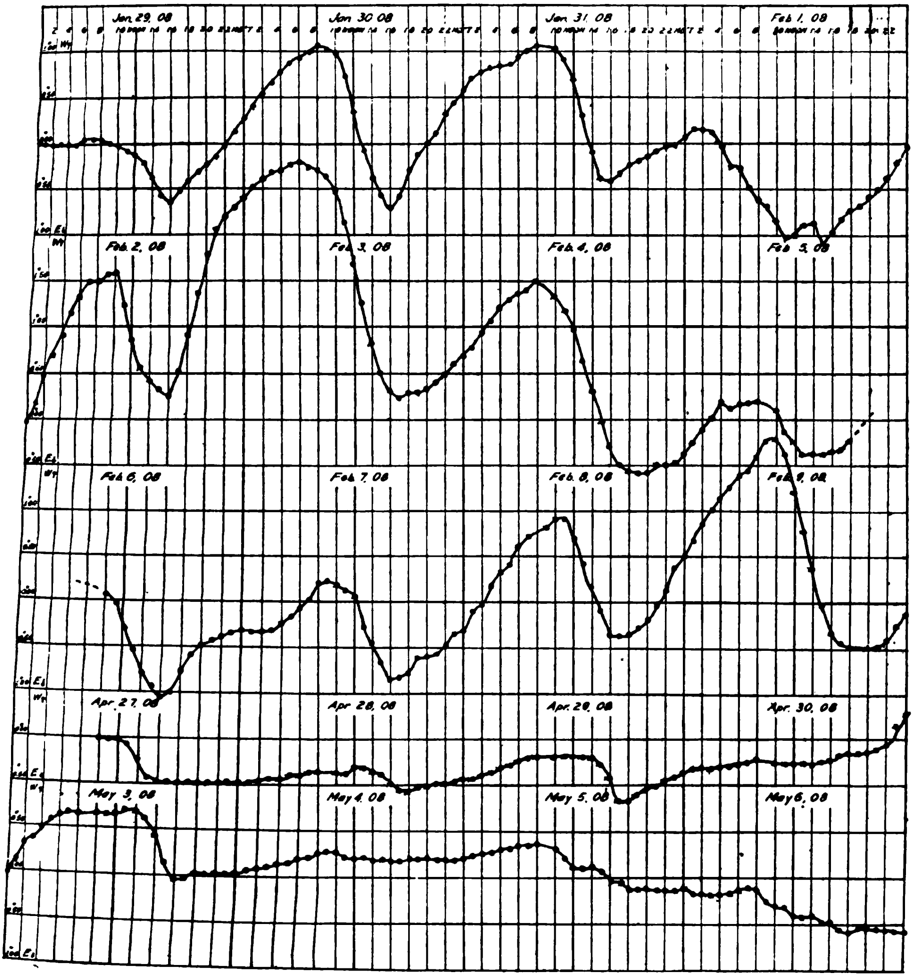
The curves in figure 3 show that shortly after sunrise, on clear days, the W-E pier began to tip toward the east, reaching its maximum east deviation about 10 A. M.; it then reversed its motion and tipped toward the west, reaching maximum west deviation about 4 P. M. (16 hrs.), and then slowly returned to its normal position. It should be noticed that all the curves show the slow tilting due to gradual changes of temperature, on which these diurnal tiltings are superposed. The tilting begins earlier in summer than in winter, but the times of maximum east and west deviation do not vary greatly with the season. The range of motion is greatest in winter, the yearly average being about one second of arc. Any cloudiness or other condition which diminishes the intensity of the sun's radiation tends also to diminish the range of tilting. This is especially noticeable in cases of fog in the morning.

The results of this tilting of the E-W pier have been recently confirmed by a similar seismograph adapted to show only the slow tilting of its pier. The heavy mass, M, carried a vane dipping in a dish of glycerine, so that all rapid oscillations were damped out. A pointer fastened on M was in contact with a small arm extending from the mirror frame of an Eschenhagen magnetic variometer. The mirror was carried by a quartz fiber and the torsion head was turned so that the arm and the pointer remained in contact. Any movement of M caused the mirror to turn. The record was obtained on bromide paper in the same way that the magnetic elements are recorded. The sensitiveness was such that any motion of M was magnified 300 times. Records were obtained from Aug. 28 to Oct. 12, 1908, and they confirm the general results stated above. They show clearly the great variation in amount of tilting on different clear days, depending apparently on the intensity of the solar radiation.

Since October, 1907, the seismograph has been mounted on a concrete pier in the new seismograph house. Here the tilting due to external temperature changes has been larger than in the former location. When the external temperature rises the pier tilts toward the east and south, directly opposite to the effect in the variation observatory. The diurnal tilting is inappreciable on the N-S component, but is well marked on the E-W component. It differs essentially from that observed in the variation house, consisting of a tilt toward the east, beginning about 10 to 11 hrs. and reaching a maximum east deviation about 16 to 18 hrs., and then returning slowly to its normal position. The diurnal oscillation is in this case a deflection to the east and return. The building is placed in the side of a gravel bank so that the west side only is exposed, all other sides being banked to the eaves with gravel. There does not appear to be any consistent relation between the tilting of the piers in the two locations, but each appears to be influenced by local causes which are somewhat obscure.

Some curves are given for the W-E component (see figure 4)

Fig. 4.



showing some extreme examples of this tilting effect during cold winter days, Jan. 29th–Feb. 9, 1908; and also the less marked effect during mild weather, in April and May.

The pronounced tilting during the period Jan. 29–Feb. 9, 1908 is due partly to solar diurnal effect and partly to large temperature variations occurring at this time, when the nights were very cold. Of this period Jan. 31st and Feb. 1st were partly cloudy and Feb. 5th was cloudy. During the period in April and May, April 27th was cloudy in the P. M., April 28th was cloudy, April 30th cloudy, and May 3d, 4th, 5th, and 6th cloudy. April 29th was clear.

An interesting effect which has been frequently noticed during the winter of 1908-9 appears as a very minute tilting of the pier back and forth of very small amplitude and irregular period of about a minute. This occurs at times when the ground is frozen and is especially noticeable when it is freezing or thawing.

No complete explanation of the diurnal tilting is evident, yet certain facts are apparent. The tilting is not due to any change in the temperature of the seismograph itself, or of the pier, since temperature changes inside the variation observatory are insignificant. While the temperature changes in the new siesmograph house are often as great as 1° C. per day, yet on two occasions a change of 2° or 3° C., produced by a lamp in the room, had no appreciable effect on the tilting of the pier. The actual tilting differs in amount from place to place, yet it appears to be a comparatively common effect.

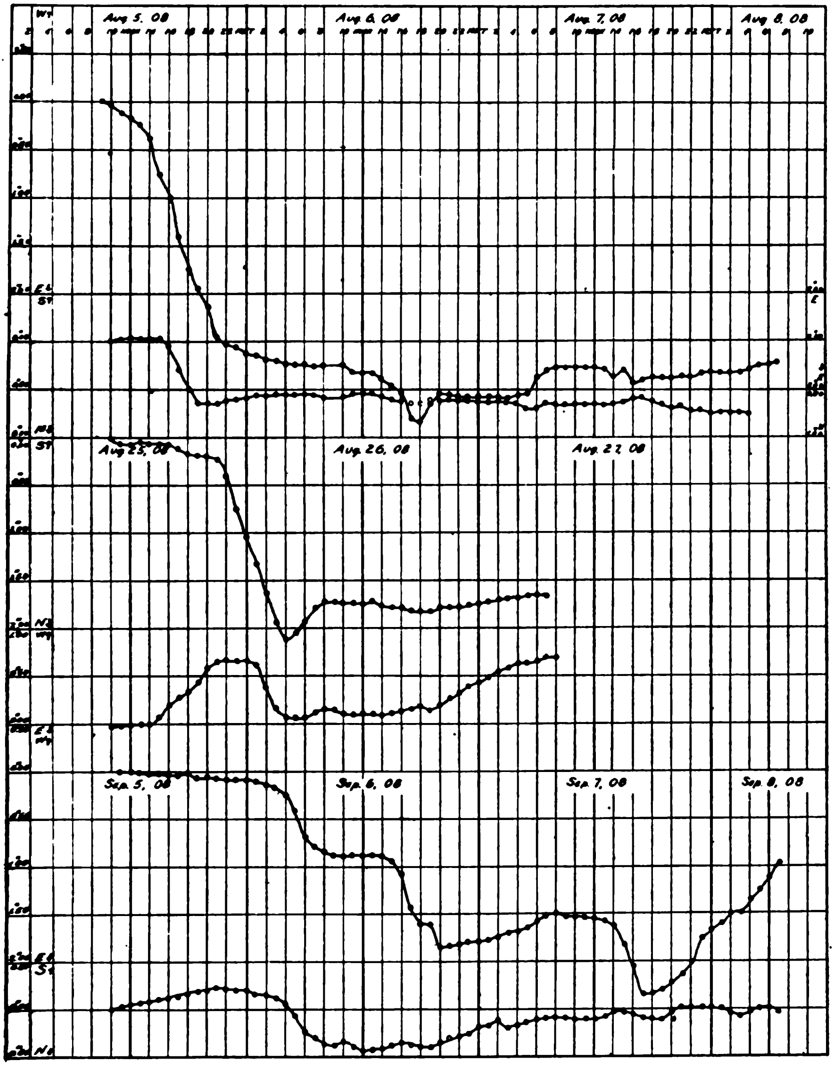
Tilting due to rainstorms.—Sudden and heavy downpours of rain do not appear to cause any decided tilting effect on the piers in the variation building. A heavy rain has, however, a decided effect in tilting the pier in the new seismograph house.

It is interesting to note that this pier always tilts toward the northeast, the E component of motion being much greater than the N component. This is possibly accounted for by the surface formation at the south and west of the house. A slight depression beginning about 50 yards southeast of the building extends around the south and west sides, being about 50 yards wide on the west side of the observatory. Up to this point its slope is very gradual and its surface is here on a level with the bottom of the pier. From this point the depression falls away more rapidly toward the north. About 50 yards northwest of the house are several springs and the soil beyond this point may be regarded as saturated with water.

The house is placed in the edge of a gravel bank, the top of which is about 15 to 20 ft. above the level of this depression, and the movement of the pier is the same as if the bottom of this depression was expanded by the water and pressed against the side of the hill.

Figure 5 gives some curves of tilting due to sudden rainstorms. That on August 5th is the best example. Between 3:30 P. M. and 5 P. M., 2·95 inches of rain fell. The ground

FIG. 5.



was very dry, as very little precipitation had occurred for several weeks. The effect was to cause a sharp tilt toward the E, which was superposed on the solar diurnal tilt already occurring, and a smaller but equally sharp tilt toward the N. The effect of the water was gradual but had reached its full amount in about 5 hours. The total displacement was about 3·00″ of arc toward the east and 0·6″ toward the north, and this condition remained practically unchanged for over 2 days. It would appear from this that the drying out of the ground had caused the pier to tip toward the southwest and the return of moisture caused a reverse movement.

Again on Aug. 25th about midnight there was a heavy rainfall the effect of which was superposed on a tilting due to the temperature change. This temperature change was such that the pier was moving toward the northwest and the rain caused motion toward the northeast, accentuating the motion in the north component and decreasing and reversing that in the E-W component. In this case there appears to have been a partial recovery due possibly to the fact that the soil had received, from recent rains, nearly its normal moisture content, and the excess soon ran through.

On September 6th during the early morning hours a heavy downpour of rain (2·34 inches) occurred. This produced a tilting of the pier toward the northeast, but the effect was superposed on a gradual temperature change and was much less than on Aug. 5th. Partial recovery appears to have occurred during the next two days. August 6th,7th, and 8th were cloudy, as was August 25th also. September 6th was cloudy during the morning while September 7th was clear. The solar diurnal tilting occurred on September 7th, and it would appear that a saturated soil may modify but apparently does not prevent this effect.

The return of the pier to its former position appears quite marked on September 7th, and it is possible that its failure to return in the first two cases was due to the cloudy weather, which prevented the ground from being dried out.

ART. XXXVII.—*The Tombador Escarpment in the State of Bahia, Brazil;* by JOHN C. BRANNER.

IN a preceding article I have described the geology of the Serra do Mulato near Joazeiro, state of Bahia;* in that article mention was made of the Tombador beds of quartzite that cap many of the mountains along the Rio São Francisco above Joazeiro. The present article describes briefly the geology of the Serra do Tombador near the city of Jacobina, from which that series of rocks was named, and the relations of those beds to older and newer rocks through the diamond regions of Bahia.

The southern extremity of the Serra do Tombador† is known locally as the Serra da Gamelleira, and is about twenty kilometers southeast of the mining town of Ventura. This southern or Gamelleira portion is cut off from the main Tombador range by Rio Jacuipe about fifty kilometers southwest of the city of Jacobina. From the Jacuipe water-gap the Tombador range runs a little east of north, always parallel with but entirely distinct from the Jacobina range, and forming the eastern rim of the Salitre Valley drainage, to the falls of Rio Salitre, some thirty-five kilometers south of the city of Joazeiro. It has, therefore, a total length of nearly three hundred kilometers on an air line.

The geology of the Serra do Tombador has long been a veritable stumbling-block in Brazilian geology. The difficulties it has created, however, are not due to the nature of its geology, but rather to the fact that it is in a distant part of the interior difficult of access, and because the information regarding its geology is scanty and consequently liable to misinterpretation.

The earliest notes, and indeed the only ones, on the geology of the Serra do Tombador proper were written by Dr. J. A. Allen, about 1868 and published in 1870 in Hartt's Geology and Physical Geography of Brazil at pages 309–313. Mr. Allen explains in his paper, however, that his trip across this region was made hastily, "the geology of the country being to me at the time a matter of secondary interest" (p. 309). Many of his observations and notes are remarkably clear and graphic, but they are necessarily fragmentary, and do not pretend to give a comprehensive idea of the geologic structure. Indeed it is not to be expected, under such circumstances, that Mr. Allen's paper would be more than a series of notes jotted down hastily, and given to Professor Hartt as of some possible use to future workers, and much better than nothing at all concerning a large and unknown part of Bahia. The route followed by Mr. Allen from Chique-Chique to the city of Bahia is a mere trail passing through a region covered with catinga forests. These forests crowd so closely on all sides that one may often travel all day without being able to see ten meters beyond the dense wall of vegetation about him. On this route, therefore, especially when one is constantly obliged to press forward in order to reach water and food for his animals, the casual traveler rarely gets an open view of the region through which he is passing, and still less frequently does he have an opportunity to know and keep track of the geologic structure and of the sequence of the rocks. It is not to be wondered at, therefore, that other persons endeavoring to use Mr. Allen's notes have failed to get a correct idea of the geology of the Serra do Tombador and of the relations of its rocks to the surrounding country.

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* This Journal, Oct., 1910, pp. 256–263.

† The Portuguese word *tombador* means tumble-down or roll-down. It is often applied to precipitous places on the side of a hill or mountain, and also to mountains themselves. In the state of Bahia alone there are two prominent ranges bearing this name. One of them is on the southeast side of the Rio São Francisco just south of Remanso, the other—the one here described—is thirty kilometers west of the city of Jacobina.

The only other naturalist who crossed this same region and who has written about the geology was Emmanuel Liais, formerly director of the Imperial Astronomical Observatory at Rio de Janeiro. In his Climats, Géologie, Faune et Géographie Botanique du Brésil published at Paris in 1872, M. Liais says (pp 180–1 and 189) that he found fossil *Lepidotus* scales and a ganoid tooth, associated with *Paludina* and *Planorbis*, at Engenho on the road from the city of Barra on Rio São Francisco to the city of Bahia. This reported occurrence of Cretaceous fossils has added greatly to the difficulty of understanding the geology of the region as a whole, largely because it was assumed that the *Lepidotus* was from the horizontal beds shown by Mr. Allen to cap the Serra do Tombador.

During the progress of the work done by the writer the Cretaceous fossils, said to have been found by M. Liais, became more and more puzzling. In order to clear up the matter a special trip was finally made to Engenho, and the road followed by him was examined across the Engenho estate. The limestones he mentions were found without difficulty, but the examination of the region made it clear that some mistake had been made with the materials collected by M. Liais, and that the conclusions drawn from them were unwarranted and quite misleading.*

* The rocks at the locality where the fossils are said to have been found are mostly in the form of loose fragments strewn down the southwestern slope of the hill near Rio Salitre. Near and at the base of the hill are out-

A general idea of the structure of the Serra do Tombador can best be had from the accompanying east-west section across the range along the road from Jacobina to Catinga de Moura. The altitude of the crest of the range where this road passes over it is 930 meters (aneroid) above tide level, or 370 meters above the fazenda Santa Cruz at the base of the mountain. The plain to the east, that is between the Serra do Tombador and the Serra de Jacobina, is made up almost entirely of granites, gneisses, schists, and old eruptives. At the fazenda Santa Cruz at the eastern base of the range hornblende schists are exposed, and at the fazenda Sitio do Meio, a little further north where the old road starts up the mountain, the rocks are granites. The hills made of these older rocks are mostly low and rounded. Some idea of the general topography, both of the granite hills and of the escarpment so characteristic of the Tombador range, can be had from the accompanying sketches.

FIG. 1.

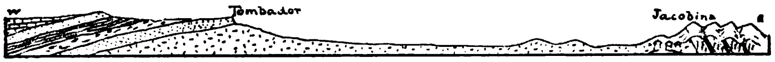

FIG. 1. General east-west section across the Serra do Tombador, the Serra de Jacobina and the valley between.

FIG. 2.

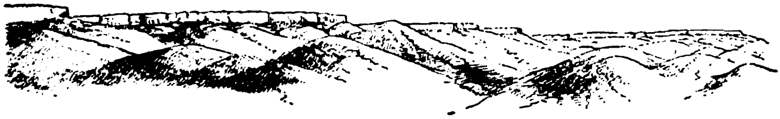

FIG. 2. Looking north-west along the eastern face of the Tombador escarpment. The rounded hills are the granites underlying the Tombador sandstone. Sketch by the author from Genepapo, 20 kilometers south of Jacobina.

In addition to these granitic hills, however, there are a few

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crops of lime rocks in place, and these rocks contain abundant remains of recent freshwater shells. But nothing was found, after the most careful search, that even suggested *Lepidotus*, or the rocks in which *Lepidotus* remains have hitherto been found in Brazil. The rocks exposed where these fossils are said to have been found are of two kinds, recent limestones and old, probably Triassic limestones. In the latter the most careful search has been made for fossils at hundreds of exposures, and not a single one has yet been found except certain small oolitic bodies that are probably algæ. One of the following conclusions is inevitable: first, that the *Lepidotus* was found elsewhere, and was credited to this locality by accidental change of label; second, that it was brought from the Cretaceous area north of the Rio São Francisco, or elsewhere, and dropped at this place; or, third, that there was an error in the identification. In any case the evidence afforded by the fossils reported from this locality by M. Liais, excepting *Paludina* and *Planorbis* which are now living in the streams and ponds, must be set aside.

peaks or sharp ridges of quartzite whose beds stand nearly or quite on end. These quartzite peaks and ridges are more or less isolated, and appear to belong to a series of sediments older than either the Jacobina range or the Tombador range.

FIG. 3.

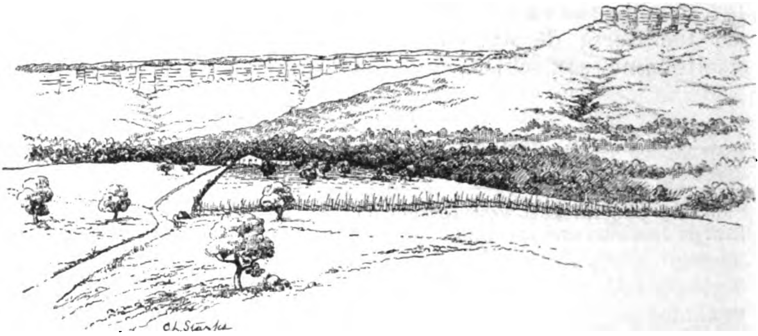

FIG. 3. Serra do Tombador seen from fazenda Santa Cruz. From a sketch by the author.

As suggested by the section and the sketches, the Serra do Tombador is formed by the edges of a resisting series of nearly horizontal beds. These beds the writer has called the Tombador series. They are sandstones and quartzites, and the series is unbroken by intercalated shales. Where the Jacobina-Chique Chique road passes the ledge this sandstone series is about a hundred meters thick, and the rocks are rather soft and much jointed, while in color they are pinkish, yellowish, reddish, and gray. They are strongly false-bedded, and on the top of the serra, where large bare surfaces are exposed and the direction of the lamination is well shown, the false dip is toward the north and northwest. Along the face of the bluffs as seen from the old trail, a couple of kilometers north of the

FIG. 4.

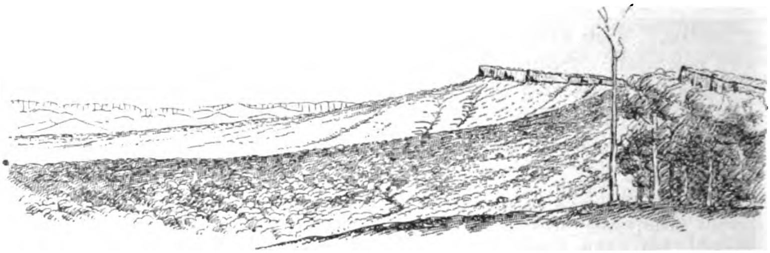

FIG. 4. Looking southwest along the east face of the Serra do Tombador from an elevation of 780 meters, and 30 kilometers west of Jacobina. From a sketch by the author.

present trail, the false beds are often three or four meters high. The general dip of the beds themselves is gentle and toward the north. At other places the dip is toward the west or northwest, but it is always in the direction of the Salitre valley, of which this range forms the eastern rim. The top of the range is a beautiful open grassy campo, whose surface dips west at an angle of four degrees. Five or six kilometers to the west these grass-covered campos merge into the catinga forests that cover all the rest of the Salitre valley.

Going westward or northwestward down the slope of the range one passes from the Tombador sandstones to a series of whitish flinty beds that the writer has called the Jacuipe flints. These flinty beds seem to overlie the Tombador sandstones conformably. They are well developed in that part of the range locally known as the Serra da Gamelleira and along the southern third of the Tombador range proper. At the fazenda do Poço close to the crest of the serra they have a measured thickness of twenty-seven meters. This, however, is not the total thickness of the flints, for the upper portion of the beds has been removed by denudation.

Thus far no fossils have been found in the flint beds, but at many places the rocks have an oolitic structure. Where they have weathered out on the surface they are often of a light gray color. This gray color is characteristic of the flints over much of the Serra da Gamelleira and over the southern end of the Serra do Tombador, but further north in the latitude of Campo Formoso they are yellowish, brown and red. Following the trail from fazenda do Poço toward Catinga de Moura, the upper limit of the Jacuipe flints is four or five kilometers northwest of the crest of the serra.

Next above the Jacuipe flints and resting conformably upon them is a series of shales that were given the field name of Caboclo shales from their development in the Serra do Caboclo on the west side of the Salitre valley. These shales vary considerably in color and thickness, but the exposure of them at this particular place cannot be regarded as typical or especially good. On this western slope of the Serra do Tombador these shales where exposed on the road are thin-bedded; the lower beds are of a light brown color, while the upper ones are light gray to nearly white with some fine-grained sandstones interbedded with them. The thickness of the shales here is estimated to be between 45 and 90 meters. The same shales are well exposed in the gorge in the lower edge of the town of Ventura, where they are of a yellowish and greenish gray color, jointed and flaggy, and have a gentle western dip. In the bluffs at Ventura these shales strongly resemble the flaggy Cayuga shales at Ithaca, New York. Although the Caboclo shales have been examined at a great many places and over large areas, no fossils of any kind have yet been found in them.

Next above the Caboclo shales is a series of sandstones which are believed to be the Lavras series of Derby.* The contact between the shales below and the sandstones above is not well exposed at this place, but in the zone of the contact, and especially where the lowest part of the sandstones has been removed by denudation, there are many heavy water-worn bowlders scattered over the surface as if they had originally formed part of a basal conglomerate. Some of these bowlders are as much as two feet in diameter.

These Lavras sandstones form a series of low hills running parallel with the Tombador range. At this place they are only from twenty to one hundred and fifty meters high, that is above the general level of the plain immediately about them. Though they can be traced for a long distance with the eye, it seems probable that they occasionally disappear altogether.

The road leading to Catinga de Moura from Jacobina was not followed further west than this range of hills formed by the Lavras sandstones. What the next overlying rocks are at this particular place cannot be positively stated from personal observation. A little further toward the northwest on the Engenho estate the rocks are limestones, and it is a matter of common information that the rocks at Catinga de Moura are limestones. Over the surface of the ground near the base of the Lavras beds fragments of the pinkish limestone so common along the Rio Salitre were found. It is, therefore, inferred that the limestone not only overlies the Lavras sandstones, but that it even encircles and passes to the east of the ridges made by those sandstones. Such relations are borne out by observations at other places in the Salitre valley.

The sequence and thicknesses of the various series observed in this section across the Serra do Tombador, as nearly as they could be made out on the Jacobina-Chique Chique road, are estimated as follows.

Salitre limestone (not seen in place)		
Lavras sandstones	46 to 60	meters.
Caboclo shales	45 to 90	"
Jacuipe flints	20 to 30	"
Tombador sandstone	90	"
Granites and gneisses at base about 250 meters visible.		

Further north the sandstones and conglomerates that give character and prominence to the southern extremity of the Tombador range become less conspicuous in the topography. North of the Jacuipe watergap, however, they do not cease to form the watershed between the Salitre drainage and the drainage into Rio Itapicurú, and into Rio do Poço Comprido. The geology of this watershed was examined by the writer at two other points further north, and the sections as there made out will be of interest in connection with the one already given.

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* O. A. Derby, Economic Geology, i, 134-142, Nov.-Dec. 1905.

A trail crosses the range between fazenda da Pedra Branca on the east and fazenda da Varzinha on the west side of the watershed. At this place the range no longer forms a bold escarpment; indeed the Tombador sandstones and the rocks that overlie them are all lacking, or are not exposed, up to the Salitre limestones which rest directly or almost directly upon the granites.

It is of interest to note that granites with a few other crystalline rocks extend from the base of this ridge eastward past fazenda Lagoa do Mato to the base of the Jacobina range, and that in this granitic area there are here and there sharp quartzite ridges with their beds standing nearly or quite on end. The fazenda Pedra Branca takes its name from one of these white quartzite hills.

The following section shows the geology as it is exposed on this trail.

FIG. 5.

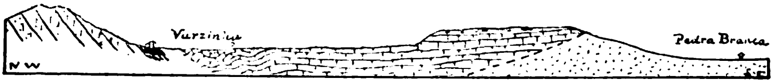

FIG. 5. Section showing the general geology between fazendas Pedra Branca and Varzinha, a distance of 18 kilometers.

The hill where the road passes over it is less than a hundred meters high. The granites at the base continue half way up the slope; above them is a narrow zone of quartzites and schists, and these are followed by decomposed cherts which cap the ridge. Going down the gentle westward slope of this ridge the cherts are found to overlie and to be part of the Salitre limestone series. The limestones are mostly compact and dark blue. They here have some thin strata of yellowish shale interbedded with them. These limestones mostly have a gentle dip toward the west; but as the mountains near Varzinha are approached the limestones are highly tilted in places.

Five or six kilometers further north the trail from Campo Formoso to Varzinha crosses this same watershed on fazenda Campo Frio. This route furnishes another section from the granite base of the Serra de Jacobina at Campo Formoso to Varzinha, which is on and near the Salitre limestones.

The road from Campo Formoso to Campo Frio is over granite all the way except near the village of Poços, where there is a little quartzite, and a few kilometers further west, where there are some thin patches of basal conglomerate resting directly on the granite. The crest of the watershed between the Salitre drainage and the Itapicurú drainage is only a kilometer or two west of the granite area. This crest is remarkably flat, the soil is of a deep red color, and the abundance of loose flint fragments on both slopes suggest that the flint-bearing beds form the crest of the divide. The topography of the watershed and the appearance of the hills to the north and west all suggest that the limestones with which the flints are associated dip gently toward the Salitre valley. Exposures of bedded limestones a few kilometers further west bear out this idea.

Attention should be called to the fact that although this watershed does not form a bold bit of topography, it has an altitude of 800 meters at the point where the trail crosses it, while the Morro da Mina, one of the prominent peaks of the Serra de Jacobina, has an altitude of 950 meters a. t. In other words, this watershed is a high one in spite of its lack of boldness, and it is the geographic prolongation of the Serra do Tombador in spite of the absence of the Tombador series of rocks.

Further north this watershed swings westward and reaches Rio Salitre at the falls of that stream some thirty-five kilometers south of Joazeiro. The Tombador sandstones again make their appearance somewhere north of the section given above, and thickening up they begin to form the bold topography just east of the cachœira do Salitre. The falls themselves are made by passing over the Tombador sandstone ledge. West of Rio Salitre they rise into the broken mountainous region and appear again capping the Serra da Cruz and Serra do Mulato as explained in the preceding chapter.*

The character and apparent structural relations of the Tombador beds to those of the Jacobina range suggest that the two ranges may be geologically identical, and that the valley between may be simply a breached anticline. The possibility of such relations was entertained in the early part of the field work, and though it was soon abandoned, it has not been lost sight of. In the total absence of fossils from the rocks of both ranges one is obliged to depend entirely upon lithologic and structural features to settle this question. The chief fact in support of the theory of the identity of the two series is that they both rest upon the old granitic series.

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* This Journal, Oct., 1910, pp. 256–263.

Against the theory of the geologic identity of the two ranges are the following facts:

First, the difference in the characters of the rocks themselves. The rocks of the Jacobina range are mostly quartzites of the kinds known in Minas Geraes as itacolumites, while those of the Tombador range are mostly ordinary sandstones. Though the Tombador beds are also sometimes quartzites, the quartzitic nature of the series is not nearly so pronounced or so universal as in the case of the Jacobina range.

Second, the absence from the Tombador range of the soft beds so characteristic of the Jacobina range. These soft beds are talcose schists or slates that break down readily and form the valleys. No such beds have yet been found in the Tombador series. In view of the fact that such soft beds make up about half of the total thickness of the Jacobina series, it seems highly improbable that they would completely disappear in the few kilometers that separate the two ranges from each other.

Conclusions:—The Cretaceous fossils reported by Liais as having been found at fazenda Engenho on the northwestern slopes of the Serra do Tombador are misleading. The fossils, if found where reported, were not in place.

The escarpment of the Tombador range is formed by a thick, horizontal series of false-bedded sandstones and quartzites, that rest unconformably upon a very old series of granites and other crystalline rocks. The sedimentary beds of the Tombador series have thus far yielded no fossils, but they are supposed to be Paleozoic, and are provisionally referred to the Silurian. They are the same as the sandstones that cap the Serra do Mulato and the Serra da Cruz, and they occur over a wide area in the interior of Bahia and along the upper valley of the São Francisco.

Overlying the Tombador beds are the Jacuipe flints, and these are followed by the Lavras sandstones and quartzites, the series of sediments in which the diamonds and carbonados of Bahia are found.

ART. XXXVIII.—*Note on the Age of the Tribes Hill Formation;* by PERCY E. RAYMOND.*

IN a recent paper on the age and relations of the Little Falls dolomite of the Mohawk Valley, Ulrich and Cushing† have separated the upper "fucoidal beds" of Emmons from the non-fossiliferous dolomite below, and have given them the formation-name Tribes Hill. This formation they consider to be of the age of the Lower Beekmantown, and state that it is separated by an unconformity from the underlying dolomite, which they assign to the Ozarkian.

In a paragraph on the age of the Tribes Hill formation, they state: "That the Tribes Hill is younger than any known Ozarkic formation is satisfactorily shown by the presence of *Asaphus* and three or four other trilobites that are wholly unknown in Ozarkic faunas. The same is true of the *Ribeirias;* and the *Dalmanella ? wemplei* also is a type that has not been observed below the Canadian. With the exception of *Eccyliomphalus multiseptarius*, the testimony of the gastropods is less positive, very similar, though specifically distinct, forms being found in Ozarkic faunas. The gastropods described by Cleland from the upper chert zone of the Little Falls dolomite at Little Falls are clearly Ozarkic types and hence are not referred to in this paragraph."

The writer has recently restudied the trilobites which occur in the fauna described by Cleland from Fort Hunter, and finds that the *Asaphus canalis ?* of that fauna is in no way related to the *Asaphus canalis* of the Beekmantown of the Champlain Valley, but belongs to that division of the Asaphidæ in which the hypostoma is not forked. The trilobite proves to belong to the genus *Asaphellus*, and is redescribed as a species of that genus in a paper now in press. The trilobite described by Weller‡ from Columbia, New Jersey, as *Isotelus canalis* may be the same species.

Another Asaphid with an undivided hypostoma is the "*Asaphus marginalis*" mentioned by Collie§ as occurring in a zone 3,750 feet below the top of the Beekmantown at Bellefonte, and as Ulrich and Cushing state, the fauna occurring with this Asaphid in the Bellefonte section is so similar to that of the Tribes Hill, that the two may safely be correlated.

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* Published by permission of the Director of the Geological Survey of Canada.

† Sixth Report of the Director of the Science Division, New York State Museum, 1910, p. 97.

‡ Pal. New Jersey, vol. iii, pl. 3, figs. 5, 6.

§ Bull. Geol. Soc. Am., vol. xiv, p. 407, 1903.

Another Asaphid of the Tribes Hill is the *Asaphus convexus* Cleland = *Bathyurus levis* Cleland = *Illænurus columbiana* Weller. The narrow axial lobe of the pygidium, as well as the general shape, show that this species is more closely related to *Symphysurus* than to the typical species of *Illænurus.* After untangling the synonymy this species appears to emerge under the name *Symphysurus convexus* (Cleland).

Except for a few species of *Nileus*, information about Asaphids with unforked hypostomas is practically wanting in America, though several species are known. For knowledge of the stratigraphic value of this group, we must, then, turn to Europe, where numerous species are known in Great Britain, France and Scandinavia. In all these countries, *Asaphellus* and *Symphysurus* occur together in the Tremadoc, above the Cambrian and below the range of Asaphids with forked hypostomas. The only *Asaphellus* previously known from the American continent is that described by Matthew* from strata immediately overlying the Cambrian on Cape Breton island. The fauna found there with the *Asaphellus* is a small one, and not closely allied to the one found at Fort Hunter.

Brögger† has pointed out that the Tremadoc (*Euloma-Niobe* fauna) occurs in America, but its exact position and full fauna have never been worked out. Brögger listed a number of species indicating this fauna in Newfoundland and in the conglomerates at Point Levis. *Niobe morrisi* (Billings) was mentioned by him as representing the Asaphids with unforked hypostoma, and to this may be added *Asaphus illænoides* Billings, which is a *Symphysurus*, and *Asaphus goniurus* Billings, a *Megalaspides.* These are, in turn, associated with *Dicelocephalus magnificus* Billings, and, therefore, older than Beekmantown. *Asaphellus* and *Symphysurus* seem, then, to be genera characteristic of the fauna immediately following the Cambrian.

With *Asaphus* removed from the list of trilobites of the fauna of the Tribes Hill the aspect is not very modern, and with the gastropods only specifically distinct from those of the Ozarkian, the whole fauna seems as much Ozarkian as Beekmantownian.

According to Ulrich and Cushing, the stratigraphy shows that the Tribes Hill formation is younger than the Hoyt formation which carries the Saratogan fauna described by Walcott. The fauna of the Hoyt limestone is stated to be similar to that of the Gasconade chert of the Ozarkian of Missouri. The top of the Gasconade chert is from 120–475 feet below the top of the Ozarkian of Bain and Ulrich's section,* so that there is a place for the Tribes Hill above the Gasconade, if it is to be placed in the Ozarkian instead of the Beekmantown.

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* Bull. Nat. Hist. Soc., New Brunswick, vol. iv, part v, 1902.

† Nyt. Mag. f. Naturvidensk., vol. xxx, 1896, p. 164.

All that we now know about the fauna of the Ozarkian is what is given by Ulrich in the paper first referred to in this note, and by Schuchert in "Paleogeography of North America." If the fauna is to be defined as consisting of "Cambrian trilobites and Ordovician gastropods and cephalopods," then the fauna of the Tribes Hill certainly has an Ozarkian aspect, with *Asaphellus*, *Symphysurus*, and *Harrisia* as the common trilobites.

Ottawa, Sept. 1910.

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* Bull. U. S. Geol. Survey, No. 267, 1905.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Metallic Radium.*—Mme. **Curie** and A. **Debierne** have prepared a small quantity of radium in the metallic state. They electrolyzed a solution of pure radium chloride containing about 0·1 g. of the salt, using a platinum anode and a cathode consisting of about 10 g. of mercury. In this way an amalgam of radium was produced, and upon distilling off the mercury in an iron boat contained in a quartz tube filled with carefully purified hydrogen, a minute quantity of what was presumably metallic radium was left behind. At 700° C. the metal began to volatilize and energetically attacked the quartz tube. It has, therefore, a lower boiling point than metallic barium. The metal shows a brilliant white luster, and it melts at 700°. It is altered very rapidly by air, becoming black, probably on account of the formation of nitride. It decomposes water energetically, most of it going into solution, so that the oxide is evidently soluble in water. Since the metal is much more volatile than barium, the authors propose to purify it by sublimation in a vacuum upon a sheet of cold metal.—*Comptes Rendus*, cli, 523. H. L. W.

2. *Separation of Antimony and Tin by Distillation.*—It is well known that arsenic may be conveniently separated from other metals for the purpose of quantitative analysis by Emil Fischer's method of distilling with ferrous chloride and hydrochloric acid. W. **Plato** has now found that it is possible to distil over antimonic chloride by the use of a stream of hydrochloric acid gas in a sulphuric acid solution to which phosphoric acid has been added, and which can be heated to a suitable temperature. The phosphoric acid prevents the distillation of stannic chloride at the same time, but after the antimony has been removed it is possible to distil over stannic chloride by elevating the temperature and using hydrobromic acid. For carrying out the operations a special, easily constructed apparatus is described, and test analyses are given which show extremely satisfactory results. The method is recommended for substances containing, besides tin or antimony or both of these, such metals as copper and lead.—*Zeitschr. anorgan. Chem.*, lxviii, 26. H. L. W.

3. *Essentials of Chemistry;* by **Rufus Phillips Williams.** 12mo, pp. 421. Boston, 1910 (Ginn & Company).—This "experimental, descriptive, and theoretical" text-book of elementary chemistry follows a series of briefer works by the same author, which have been extensively used in our schools. In the preface is set forth a list of 21 "innovations and departures from the author's previous works, as well as from current texts." Many of these changes relate to the arrangement of the matter and the

manner of presenting the subject. The book appears to have many excellent features, and it presents a rather extensive course. The illustrations and diagrams are generally good, the experiments are numerous and instructive, and the theory for the most part is clearly presented. However, the author persists in giving incorrect formulas for the common elementary gases, H, O, N, for example, instead of H_2, O_2, N_2, and in this way his "original device of diagrams" for explaining Avogadro's law gives an entirely false impression of the subject, while the simple matter of gaseous combination is at the same time made exceedingly difficult, if not impossible to understand. A good many misprints or misstatements have been noticed. A serious mistake is made in describing an electrolytic apparatus for manufacturing caustic soda, where it is stated that the sodium chloride is *fused* in contact with a layer of *mercury*, an impossible condition of things on account of the temperatures at which mercury boils and salt fuses. H. L. W.

4. *A Text-Book of Organic Chemistry;* by WILLIAM A. NOYES. 12mo, pp. 537. New York, 1910 (Henry Holt & Co.).—This is a revised, second edition, of the work which appeared about seven years ago. It is so well known to the chemical public that it requires no special comment, except that a few changes and additions have been made, most of which were prepared for the German edition, and that the short final chapter on compounds of interest in physiology and pathology has been re-written. H. L. W.

5. *Allen's Commercial Organic Analysis,* Fourth edition; edited by W. A. DAVIS and SAMUEL S. SADTLER. Vol. III, 8vo, pp. 635. Philadelphia, 1910 (P. Blakiston's Son & Co.).—This important work, which is being entirely re-written in the present edition, will consist of eight volumes when complete. The third volume, under consideration, treats of the hydrocarbons, including olefines, acetylenes and tars, bitumens, including the various petroleum products and the coal-tar hydrocarbons, naphthaline and its derivatives, anthracene and its associates, phenols, aromatic acids, gallic acid and its allies, phthalic acid and phthaleins, and modern explosives. H. L. W.

6. *Analytical Chemistry. Volume II, Quantitative Analysis;* by F. P. TREADWELL. Translated by WILLIAM T. HALL. 8vo, pp. 785. New York, 1910 (John Wiley & Sons).—This excellent text-book, which now appears in the second American edition, has been compared with the fourth German edition. The total issue of the book, six thousand copies, indicates that it is very extensively used in the United States. H. L. W.

7. *Ozone and Ultra-Violet Light.*—It has been supposed that ozone is produced in the upper regions of the atmosphere by means of sunlight, and the ionizing effect of this light—mainly coming from short wave lengths—has been supposed to influence the transmission of electrical waves. E. v. BAHR concludes that since the ozonizing rays are strongly absorbed by air the ozoniz-

ing effect must be limited to the extreme upper regions of the atmosphere; but in these regions the deozonizing effect of sunlight is also very strong, and it does not seem probable that a noticeable quantity of ozone exists there.—*Ann. der Physik*, No. 13, pp. 598–606. J. T.

8. *Influence of Pressure upon the Absorption of Ultra-Red Radiation in Gases.*—E. v. **Bahr** concludes that an increase of pressure results in both a qualitative and quantitative change of the absorption of oxide of nitrogen; and that the qualitative change of the absorption is important only with low pressures. The absorption band at very low pressures consists of fine lines, which, however, quickly broaden with increase of pressure, and run together at a pressure of 50^{mm}.—*Ann. der Physik,* No. 13, pp. 585–597. J. T.

9. *Metallic Radium.*—Madame **Curie** describes her method of obtaining metallic radium. The principle of the method consisted in preparing an amalgam of mercury and metallic barium, and a process of distillation to get rid of the mercury. At the end of the process, a brilliant white metal was obtained which melted at approximately 700° C. It adhered strongly to iron, altered very rapidly in air, blackening immediately. Particles of the metal put upon paper produce a blackening analogous to a burning effect. In contact with water the metal is energetically decomposed.—*Comptes Rendus,* Sept. 5, 1910. See also on p. 347. J. T.

10. *Wireless Telegraphy.*—**Marconi** states that messages have been transmitted between Clifden, Ireland, and Glen Bay, Canada, in daylight. The distance is 3500 miles. A pole was used for the support of the aërial wire on the vessel. The greatest previous distance at sea was 1750 miles.—*Nature*, Sept. 29, 1910. J. T.

11. *A New Alloy.*—The chief chemist of the works of Messrs. Vickers Sons & Maxim announces the discovery of an alloy, which he calls Duralumin. It is slightly heavier than aluminium, it is strong as steel, and can be rolled, drawn, stamped, extended or forged at suitable temperatures. It is less corrodable than other alloys of aluminium and is one-third the weight of brass.—*Nature*, Sept. 8, 1910. J. T.

12. *Handbuch der Spectroscopie;** by H. **Kayser.** Vol. V. Pp. vi, 853, with 2 plates and 3 figures. Leipzig, 1910 (S. Hirzel).—This volume contains *all* the reliable data pertaining to the spectra of fifty elements. The subject matter is arranged alphabetically with respect to the chemical symbols of the elements and hence the list ends with nitrogen. Such rare or hypothetical elements as coronium, davyum, demonium, radium emanation, holmium, incognitum and ionium of Crookes are included. In addition, the spectra of air, lightning, the aurora borealis and meteors, as well as the spectroscopic phenomena associated with the Bessemer process, are discussed. The remainder of the elements will be treated in a similar, exhaustive manner in volume VI.

* See this Journal, vol. xxv, p. 522, 1908.

The bibliography of the (alphabetically) first elements is complete through the year 1908 and it has been carried right up to date for the last elements. Very great care has, also, been taken to avoid errors in the tables of wave lengths. Consequently, volumes V and VI will be of great value to a much wider circle of readers than the preceding volumes, inasmuch as the bibliographic lists and the numerical tables will appeal to any investigator in any subject who needs such data, whereas the first four volumes deal with material which is of interest chiefly to workers in the comparatively special field of spectroscopy. Judged by this standard, volume V is by far the most important work on the subject extant. H. S. U.

13. *Physical Measurements;* by A. W. DUFF and A. W EWELL. Second edition. Pp. xi, 256. Philadelphia, 1910 (P. Blakiston's Sons & Co.).—This is the second edition of a laboratory manual previously reviewed in this Journal (June, 1909). It retains the many excellent qualities of the first edition, and has been somewhat enlarged. The typography and diagrams have been distinctly improved. H. A. B.

14. *Der Lichtbogen als Wechselstromerzeuger;* von WILLY WAGNER. Pp. vi, 119. Leipzig, 1910 (S. Hirzel).—This book gives a connected account of the work which has been done during the last ten years upon the electrical oscillations set up when an arc is shunted by capacity and inductance. The theory of the phenomenon is discussed and the applications to wireless telegraphy and telephony are described. Considerable attention is given to the author's own work on metallic arcs. H. A. B.

II. GEOLOGY AND MINERALOGY.

1. *Diverse Effects of Glaciation on the Cretaceous Clays;* by A. C. HAWKINS. (Communicated.)—Heinrich Ries, in his recent book* dealing with clay deposits, describes types of deformation in clays, as follows: "Beds of clay and shale sometimes show folds or undulations.—Many clay deposits in the Northern States show a local folding caused by the shoving action of the ice-sheet during the glacial period. Such folds, however, are of minor account, and affect only a few beds.—Where a bed is not sufficiently elastic to bend under pressure, it breaks, and if, at the same time, the beds on opposite sides of the break slip past each other, faulting is said to occur.—Every bed terminates abruptly at the fault-plane, its continuation on the other side being at a higher or lower level. Displacements of this type are somewhat rare in surface clays, and if occurring, the throw is not apt to exceed a few feet."

An excellent case of each of the foregoing types has been brought to light by recent excavations in the Cretaceous clays of the Perth Amboy district in New Jersey. In these exposures, the structures were so admirably shown that the writer has thought it worth while to make a note of the occurrence.

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* Heinrich Ries: "Clays, their Occurrence, Properties, and Uses," pp. 28–30.

When first met with in the field, these dislocations in the clays were thought to be due to glacial pressure; and we have been strengthened in this opinion by the receipt of certain letters from Dr. H. B. Kümmel, State Geologist of New Jersey, who says in part: "I have yours of July 3d and also the photograph which you so kindly sent me. It certainly shows a very good example of a local fold in the upper part of the clay, caused by the ice movement." "The faults in the clay bed at Maurer are, in my opinion, probably due to disturbances during the glacial period, as I have observed similar faults in a number of pits in Middlesex County where the glacial drift overlies the Cretaceous, whereas in non-glacial portions of the state faults in the Cretaceous are very rare."

FIG. 1.

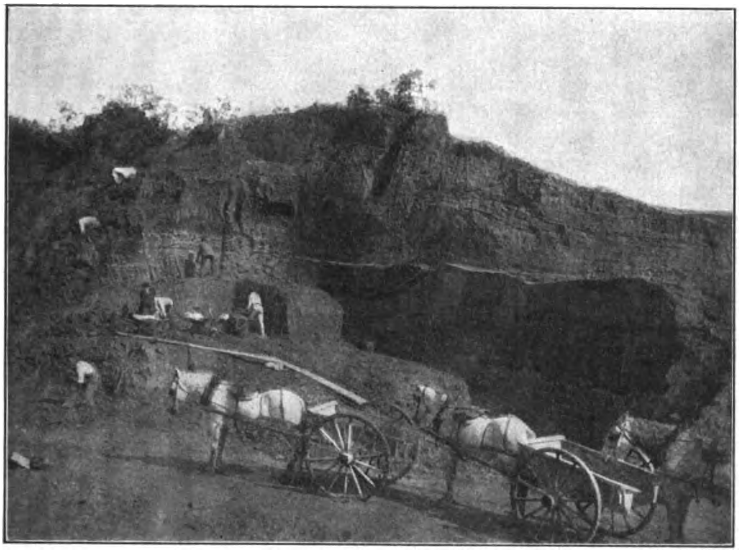

FIG. 1. Folding in Cretaceous clays resulting from glacial pressure.

Both of these exposures were made in the process of mining brick and fire clays by the usual open cut method. The faulting (fig. 2), which occurred at Maurer, Middlesex Co., took place in dark and light gray, plastic brick clays, in the upper part of the so-called Woodbridge clay horizon. The folding (fig. 1), seen two miles farther west, near Woodbridge, in the same county, took place in clays of a slightly lower horizon in the same series, very similar in color, though more thinly laminated and sandy than the higher beds.

The anticlinal folding (fig. 1) was exposed in a pit now being worked near the road leading from Metuchen to Woodbridge, this road being a continuation of Main street (Woodbridge) and the location about half a mile west of the latter town. The floor of the pit is about 25 feet below the level of the road at this point, and on its south side. A beautiful 15 foot anticline in the clays on the west side of the pit was formerly conspicuous, but has since slumped down. The present smaller fold is in the south wall, and at the time when the photograph was taken was at the principal point of attack on the clay deposit. To right and left of the fold were thinly laminated clays in alternating dark and light layers, forced up into close plications, much like the smaller plications in the pre-Cambrian gneisses. Under the crest of the main anticline there was a noticeable thickening of one layer, evidently due to the squeezing up of the bed into the space under the arch, as the latter was raised. The apparent unconformity (disconformity) in the wall near the floor of the pit was probably due to irregularity of deposition.

Fig. 2.

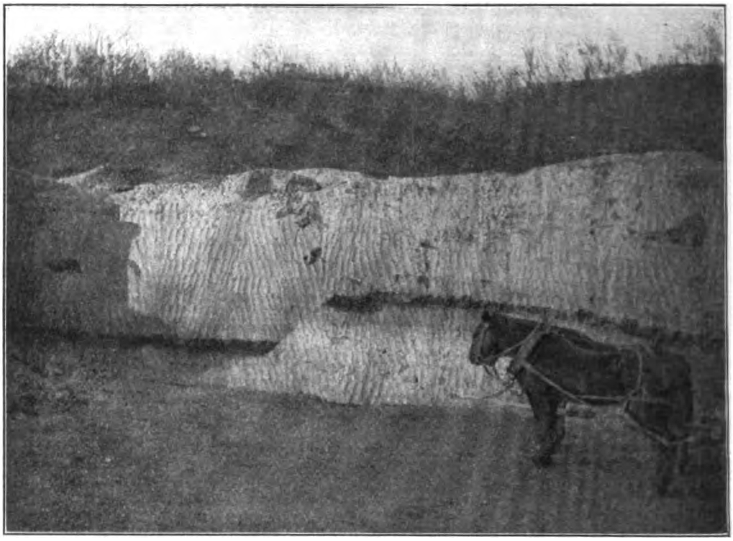

Fig. 2. Faulting in Cretaceous clays resulting from glacial pressure.

The second exposure (fig. 2) was made in the process of removing a clay deposit in a small hill, just east of the C. R. R. tracks

(Long Branch Division), and about 200 yards south of the station at Maurer, Middlesex Co., in a pit known as Dunnigan's pit. The excavation, having proceeded at a level slightly below the railroad for some 200 feet into the hill, developed a vertical wall of clay, in which was shown the faulting herein described. This wall or quarry face was 150 feet long and 7 to 10 feet high, and showed, as it progressed, five or six separate faults, each of which slightly dislocated the layers of the deposit.

The clays here, as elsewhere in this region, are nearly horizontal, having a dip of only 35 to 60 ft. per mile toward the southeast. They form part of a coastal plain deposit, on which, as the prominent black lignite seam in the section shows us (see fig. 1), vegetation grew for a certain period, to be overwhelmed again after a time by the clay deposition. It will be noted that the layers of clay immediately above and below the lignite are darker in color than those farther away from it, in this case indicating a larger portion of carbonaceous matter in the former. The clay layer below the lignite seam shows numerous woody lignite fibers, extending downward in a vertical direction. These without doubt represent the roots of the earliest vegetation which furnished the lignite. Seams of this kind are very uncommon in the pits of Middlesex County, though isolated logs and stumps of lignite are common.

It will be noted that but for the presence of the black seam and the darker clays surrounding it, there would be no well-marked evidence of any faulting, because of similarity in the color and texture of the beds. Even a very close scrutiny of the clay wall failed to show any noticeable crevice along the fault plane which subsequent pressure had not completely closed. Even the fault scarp, which would normally appear at the top, was completely removed by the glacial action, and the bowlder clay, which was later deposited above, of course can show no evidences of the faulting, of which it is entirely independent.

The several faults exposed were all parallel in strike, which was roughly N–E–S–W, at right angles to the movement of the ice, which is suggestive. Moreover, the downthrow, which varied from four inches in the smallest one to about two feet in the one here figured, was in every case toward the southeast, away from the source of pressure.

Some interesting geological speculation might be based on these phenomena. For example, why did folding take place in one case and faulting in another? Why are not phenomena of this kind more common in those clay deposits which lie within the terminal moraine? Was the local deformation due to excessive thickness of the ice, or to local weakness in the clay, and if so, may it not have been a similar local variation in strength that caused folding in one case and faulting elsewhere?

Mineralogical Department, Princeton University.

2. *The Middle Devonian of Ohio;* by CLINTON R. STAUFFER. Geol. Surv. Ohio, Bull. 10, 1910, 204 pages and 17 plates.—The author here presents in detail an excellent and up-to-date account of the Middle Devonian stratigraphy and faunas scattered along the eastern and northern sides of the Cincinnati arch. At the base is the Columbus limestone, 105 feet thick in central Ohio, thinning to 61 feet at Sandusky and to 55 feet west of Toledo. Over it lies the Delaware limestone, 36 feet thick, followed by the Olentangy shale of 31 feet thickness. The last two formations cannot be recognized as such in the northwestern corner of Ohio, and here the Columbus limestone is overlain by the Traverse formation seemingly not over 47 feet in thickness.

The Columbus coral reef fauna, also rich in brachiopods and especially in gastropods, is very large and has 337 species. The Delaware has 141 and the Olentangy 52 forms. The deposits are continuous in deposition, proven by the fact that 75 species of the Columbus fauna go into the Delaware, while a little more than one-half of the Olentangy fauna is derived from below. The Columbus fauna correlates well with the Onondaga of the New York standard section, while the Olentangy shale agrees best with the lower Hamilton; the Delaware, on account of continuing the limestone facies of the Columbus, retains much of its fauna but the new migrants point to Marcellus time. The Traverse fauna consists of 128 species, is decidedly Hamilton in aspect and links directly with the development as exposed about Thedford in western Ontario. The interrelation of the Ohio Basin fauna with those of New York and the Indiana and Michigan basins is fully discussed, and the areas of faunal spread are shown on two paleogeographic maps. C. S.

3. *Palæoniscid Fishes from the Albert Shales of New Brunswick;* by LAWRENCE M. LAMBE. Canada, Geol. Surv. Branch, Memoir No. 3, pages 35, plates 11, 1910.—From the petroleum- and sulphate of ammonia-bearing dark shales of New Brunswick the author here describes at length five species in three genera of ganoid fishes. The Albert shales are held to be synchronous with the Carboniferous Sandstone series of Mid and West Lothian, Scotland. The latter are considered by the British Survey "to form the base of the Carboniferous system in that country." C. S.

4. *Outlines of Geologic History with especial reference to North America.* Symposium organized by BAILEY WILLIS: Compilation edited by ROLLIN D. SALISBURY. Pp. 306, 1910 (University of Chicago Press).—The above title is the one of the title page but the book will be known as "Outlines of Geologic History." Few will recognize in either of these titles the symposium on Correlation organized by Willis and presented before Section E of the 1908 meeting of the American Association for the Advancement of Science at Baltimore. The various essays of this symposium were with one exception printed in the Journal of Geology during last year and all are here reprinted in more

convenient form. The printing and appearance of the book is good and the volume is well worth the money asked for it ($1.50 net).

There are 14 essays, describing the historical geology of North America, by Van Hise, Adams, Walcott, Grabau, Weller, Girty, David White, Williston, Stanton, Knowlton, Dall, Arnold, Osborn and Salisbury. Willis presents 15 paleogeographic maps with short descriptions of each one. The last essay of the book is by Chamberlin on "Diastrophism as the Ultimate Basis of Correlation," and Macdougal has one on "Origination of Self-generating Matter and the Influence of Aridity upon its Evolutionary Development."

Of new matter there is on page 37 a short note by Walcott in regard to the range of *Holmia* in the Cordilleran region; on page 85 an eighteen-line note by Grabau in regard to the character of the St. Peter sandstone in reply to Calvin's doubts as to the aeolian origin of this formation; and on page 125 a three-line note by Girty. Chapter 13 by Osborn did not appear in the Journal of Geology and is entitled "Correlation of the Cenozoic through its Mammalian Life." C. S.

5. *Paleontology and the Recapitulation Theory;* by E. R. CUMINGS. Proc. Indiana Acad. Science, Meeting of 1909, pages 36.—Professor Cumings here answers the critique of the recapitulation theory or biogenetic law by Montgomery in his "An Analysis of Racial Descent." His conclusions are as follows:—

"Paleontologists almost universally accept the theory of recapitulation. Its chief critics have been embryologists. The reason for the difference in attitude is probably to be sought in the fact that the former ordinarily compare epembryonic stages with adult characters of geologically older species, while the latter too often compare embryonic stages with the adult stages of existing species. It is also to be noted that in recapitulation we have to do with morphological and not with physiological characters, and that the row of cells from the egg to the adult may be morphologically the same in two organisms while being at the same time physiologically different. Until it can be shown that two organisms morphologically different in the adult must of necessity be morphologically different at all stages, the argument of Montgomery, Hurst and others proves nothing.

"In the Cephalopoda, Pelecypoda, Gastropoda, Brachiopoda, Trilobita, Bryozoa, Graptolites, Echinoderms and Corals, examples are pointed out in which there is clear and unmistakable evidence of recapitulation. In most of these cases it is the epembryonic and not the embryonic stages that are the basis of comparison."

The paper also cites the more important literature treating of recapitulation. C. S.

6. *Ordovician Stromatoporoids,* paper No. 7; by W. A. PARKS. Univ. of Toronto Studies, Geological Series, 1910, pp. 52, pls. 21-25.—Here are described 19 forms of American Ordo-

vician stromatoporoids in 4 genera ; 1 genus and 9 species or varieties are new. Their study has proven to be very time-consuming due to the poor preservation of this material in the Ordovician. C. S.

7. *Fossil Plants:* A text-book for Students of Botany and Geology ; by A. C. SEWARD. Vol. ii, small 8vo, pp. viii, 624, with frontispiece and 376 illustrations in text. Cambridge, 1910 (The University Press).—It is now nearly twelve years since the publication of the introduction to the modern methods of fossil plant study constituted by vol. i of Professor Seward's invaluable work. With its six most instructive preliminary chapters, followed by the consideration of the thallophyta, bryophyta and equisetales, that volume virtually marked a new era in paleobotanic texts, and was indeed very soon followed by those philosophic "Studies in Fossil Botany" by Scott, by the admirable "Eléments de Paléobotanique of Zeiller and by Polonié's "Pflanzenpaleontologie," while the progress of the preceding decennial had been so well recorded in that most usable of manuals, Solms' Fossil Botany.

Though with each year we looked forward to the appearance of the second volume of Fossil Plants, it was perhaps as much a necessity as "a Fabian policy" to delay its appearance till now; for progress in Paleobotany has been so rapid in the past twelve years that, as Professor Seward says, he has "decided to take the consequences of having embarked on a too ambitious plan of treatment and to preserve the uniformity of proportion by reserving the seed-bearing plants (with geographic distribution) for a third volume." Meantime one can scarce avoid taking very seriously the author's promise of "as little delay as possible in its preparation" ; for its field has become a notable one.

In the volume before us the subjects treated are, then, the Sphenophyllales (continued), Psilotales, Lycopods, Sigillaria, Stigmaria, and the now so much realigned Filicales, exclusive of the seed-bearing section or the Pteridosperms, or "pseudo-ferns." A peculiarly usable feature of the work is the introduction of these major divisions by the illustration and description of suggestive types from existing floras. This is a great book, and its perusal clearly shows that we are only beginning to recognize the significance of the fact that in Paleobotany more than in either vertebrate or invertebrate paleontology, we have the immense advantage of ever and anon interpreting outer morphology in the light of full details of histologic structure.

As really pertaining to discussion that will more properly fall within the scope of Professor Seward's third volume, it may be scarcely fair to single out an error in relation on page 396, where Crossotheca is spoken of as a type of frond,— "always regarded as Marattiaceous until Kidston proved it to be the microsporophyll of Lyginodendron." In the first place an adumbration of the fact that much of the fern foliage of the paleozoic must be in some way anomalous occurs in the work of Stur. Nearly thirty years ago he fairly wrote that, "The discovery that in the Culm and Carbon fertile ferns were really abundant . . . brings me to a further observation. Since great numbers of sterile fronds from these horizons known under the names of Neuropteris, Alethopteris, Odontopteris, Dictyopteris, etc., and thus far held to be ferns, have never been found fertile despite the diligent search of many investigators, such forms cannot be ferns . . . . are *Nichtfarne.*"

And specifically, quite five years before Kidston's determination, it was stated in this Journal (June, 1901, pp. 433–435) that in view of the Marattiaceous form of the fertile frond of Cycadeoidea, "an extraordinary interest will henceforth attach itself to the fructifications of the Calymmatothecan and Scolecopteran type, as well as to the possibility of accompanying Macrosporophylls." Indeed Crossotheca itself was mentioned in this connection, and it was concluded probable that the dimorphism of various paleozoic plants usually referred to the ferns, "is intimately connected with forms of heterospory and the acquiring of the seed habit. . . . " Interpretation of evidence could scarcely have gone further or been more obvious, and it should not be necessary to lose sight of historical perspective while enforcing the all-important lesson of the "futility of dogmatic assertions" based on the outer form of ferns, or may one add, of Angiosperms. G. R. W.

8. *Canada, Department of Mines.*—Recently received publications are noted in the following list:

GEOLOGICAL SURVEY BRANCH.—Summary Report of the Geological Survey Branch for the Calendar year 1909. Pp. viii, 307. No. 1120.

A Geological Reconnaissance of the Region traversed by the National Transcontinental Railway between Lake Nipigon and Clay Lake, Ontario; by W. H. COLLINS. Pp. 67, with 2 plates and one diagram. No. 1059.

Memoir No. 7. Geology of St. Bruno Mountain, Province of Quebec; by JOHN A. DRESSER. Pp. 33 with 3 plates and 2 maps. No. 1077.

A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, Yukon, and North West Territories. By JOSEPH KEELE. Pp. 54, with 19 plates and one map. No. 1097.

Memoir No. 3. Contributions to Canadian Palæontology. Volume III (quarto). Part V.—Palæoniscid Fishes from the Albert Shales of New Brunswick. By LAWRENCE M. LAMBE. Pp. 69, with 11 plates. No. 1109. See p. 354.

MINES BRANCH.—Summary Report of the Mines Branch for the Calendar year ending December 31, 1909. Pp. ix, 181, with 4 plates. No. 63.

Annual Report of the Division of Mineral Resources and Statistics on the Mineral Production of Canada during the Calendar years 1907 and 1908. JOHN McLEISH, Chief of the Division of Mineral Resources and Statistics. Pp. 286. No. 58.

Bulletin No. 2. Iron Ore Deposits of the Bristol Mine, Pontiac County, Que. Magnetometric Survey, etc.; by E. LINDEMAN. Magnetic Concentration of Ores; by GEO. C. MACKENZIE. Pp. 15, with 2 plates and 2 figures.

Bulletin No. 3. Recent Advances in the construction of Electric Furnaces for the production of Pig Iron, Steel, and Zinc; by EUGENE HAANEL. Pp. 76, with one plate and 17 figures. No. 68.

Report of Analyses of Ores, Non-Metallic Minerals, Fuels, etc. made in the Chemical Laboratories during the years 1906, 1907, 1908, arranged by F. G. WAIT. Pp. 126 with 2 plates. No. 59.

Map of the Porcupine Gold Area, districts of Sudbury and Nipissing, Ontario; by A. G. Burrows, geologist, and W. R. Rogers, topographer.

9. *Barbierite*, a Monoclinic Soda Feldspar; by WALDEMAR T. SCHALLER. (Communicated.)—The existence of a monoclinic dimorphous form of albite, isomorphous with orthoclase, has long been suggested, but the presence of soda in orthoclase analyses has generally been otherwise explained. In such cases the presence of albite or anorthoclase has generally been suggested as the explanation of the soda present. In a recent paper by Barbier and Prost,[*] analyses are given of feldspars in which the cleavage angle varies but a few minutes from 90° and in which soda is present in molecularly greater amount than the potash. The maximum soda content is reached in a feldspar from Kragerö, Norway, in which only 1·15 per cent K_2O was found.

Examination under the microscope showed that (with one exception) albite was not present, and the existence of a monoclinic soda feldspar isomorphous with orthoclase must be admitted. I propose to call this particular monoclinic soda feldspar *barbierite*, in honor of Prof. Ph. Barbier, of the University of Lyons, France, who has recently published, in addition to the paper above cited, another one on the feldspar group, in which he gives a definite chemical difference between orthoclase and microcline.[†] Further analyses of soda-rich orthoclases are given by him in a later paper.[‡] The feldspar from Kragerö is nearly pure barbierite.

In a very recent number of the Neues Jahrbuch für Mineralogie, etc., Angel gives a description of a soda-bearing monoclinic sanidine,[§] which contains 4·92 per cent Na_2O and 6·73 K_2O. The cleavage angle (001) : (010) is 90° 01′ and the extinction on (001) is parallel. The feldspar is monoclinic and consists approximately of equal parts of the isomorphous orthoclase and barbierite. In this paper are given several references to earlier ones on feldspars which undoubtedly contain barbierite in isomorphous admixture. See also, for example, the orthoclase described by Ford.[*]

---

[*] Barbier, and Prost, A., Sur l'existence d'un feldspath sodique monoclinique, isomorphe de l'orthose, Bull. Soc. Chim., III, p. 894, 1908.

[†] Barbier, Ph., Recherches sur la composition chimique des feldspaths potassiques, Bull. Soc. Franc. minéral., vol. xxxi, p. 152, 1908.

[‡] Barbier, Ph. and Gonnard, F., Analyses de quelques feldspaths francais. Bull. Soc. Franc. minéral., vol. xxxiii, p. 81.

[§] Angel, Franz, Über einen Natronsanidin von Mitrowitza, Neues Jahrb. Mineral. Geol. u. Pal., Beilage-Band, xxx, 254, 1910.

Chemical Laboratory, U. S. Geological Survey.

10. *Brief notices of some recently described Minerals* (see p. 90, vol. xxx).—**Wiltshireite** is a new species from that most prolific locality, the Binnenthal in Switzerland; it is described by W. J. Lewis. It occurs in small crystals grouped in parallel position and associated with sartorite in a cavity in the well-known dolomite of the region. The color is tin-white with occasionally a russet tarnish. The material thus far available is too scanty for a determination of the chemical composition, but it is regarded as probably a sulpharsenite of lead. The crystals are monoclinic and are referred to the axes: $a : b : c = 1·587 : 1 : 1·070$; $\beta = 79^\circ$ 16. The habit is prismatic, the crystals being elongated in the vertical direction, in which zone the faces are strongly striated. The hemidomes are, however, smooth and bright and the same is true of the hemipyramids. The mineral is named in honor of the late Rev. Thomas Wiltshire, at one time Professor of Mineralogy in Kings College, London.—*Phil. Mag.*, September, 1910, p. 474.

Minguetite is a hydrated iron silicate described by A. Lacroix and regarded by him as intermediate between stilpnomelane and lepidomelane; it had been called biotite. It forms masses of a greenish black color consisting of confused aggregates of small brittle plates; these are opaque except when very thin and in that case they show a dislocated black cross of negative character. The specific gravity is 2·86 and the composition is given by the analysis (by Pisani):

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O
43·65	5·22	18·80	19·00	3·22	0·94	0·66	3·00	6·00 = 100·49

From the above the formula calculated is $17SiO_2 . 4Fe_2O_3 . 8FeO . K_2O . 8H_2O$. A small part of the ferric iron is replaced by aluminium. The name given refers to the mine, Minguet, at which it was found; this is situated in the Segré region, Maine et Loire, France.—*Bull. Soc. Franç. Min.*, xxxiii, 270.

Stellerite is a zeolitic mineral allied to heulandite and stilbite, described by J. Morozewicz from a diabase tuff on one of the Commander islands in Bering Sea. It occurs in crystals which are orthorhombic both in form and optically; these are tabular in habit. resembling stilbite, and show perfect cleavage parallel to *b*. Hardness 3·5–4, specific gravity 2·12. Analysis gave:

	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	H_2O
2 2	59·23	14·41	0·22	8·23	*tr.*	18·15 = 100·24

From this the formula obtained is $CaAl_2Si_7O_{18} . 7H_2O$; this is peculiar in its seven molecules of water.—*Anz. Akad. Wiss. Krakau*, 1909, p. 344; quoted in *Jahrb. Min.*, ii, 25 ref., 1910.

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[*] On Orthoclase Twins of Unusual Habit, this Journal, xxvi, p. 149, 1908.

TURANITE and ALAITE are two new vanadium minerals, announced but not as yet fully described by K. Nenadkewitsch. They come from the mines of Tjuja-majun in the foothills of the Alai mountains in Central Asia, and occur in a coarse granular calcite. Turanite forms compact aggregates, reniform and radiated in structure, and is stated to have the composition $5CuO . V_2O_5 . 2H_2O$. Alaite is a decomposition product having a dark red color and silky luster; to it the formula $V_2O_5 . H_2O$ is assigned. Analyses and full descriptions follow later.—*Bull. Acad. St. Pet.*, 185, 1909, noticed in *Jahrb. Min.*, i, 193 ref., 1910.

11. *Les Roches alcalines de Tahiti;* par A. LACROIX. Bull. de la Soc. Géol. de France, 4 ser., x, p. 91, 1910.—In this article the writer describes a series of alkaline rocks from the valley of the Papenoo River in Tahiti. The massive granular types include nephelite-syenite, monzonite containing nephelite, theralite, and essexitic gabbro. The calculation of the norm from the chemical analysis of the latter shows it to fill an unnamed subrang in the quantitative classification for which the term *papenoose* is proposed. Of attendant dike rocks, tinguaites, camptonites, monchiquites, and microgabbros are described, while the effusives comprise phonolites, hauynophyres, basalts, and picrites. Of most of these analyses are given. From this it will be seen that the series presents a well-defined clan of typical alkalic character. Regarding the occurrences, areas, and geological relations not much has, as yet, been learned, owing to the denseness of the vegetal covering.

Although the finding of new occurrences of alkalic groups of this kind is always interesting from several points of view, it is doubly so in this case. The discovery of rocks of continental types in this part of Polynesia in mid-Pacific is of wide geological importance. Moreover, it has been claimed by Harker, Becke, and others that the igneous rocks of the Pacific basin are of sub-alkalic (alkalicalcic) nature, those not in this hemisphere generally speaking alkalic. With typical alkalic groups, or members, turning up in Hawaii, Easter Island, Clipperton atoll, Samoa, Fiji, and now at Tahiti, it would be well, as Lacroix remarks, to use the terms of alkalic and alkalicalcic (sub-alkalic) groups, and to avoid the geographical designations of Atlantic and Pacific, until further research has shown that the generalizations, on which these terms are based, are really well founded. It begins to appear to the reviewer as if the rocks of the mid-Pacific might belong to an alkalic petrographical province, and the alkalicalcic to a broad circumferential belt related to the edges of the continental platforms. L. V. P.

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VOL. XXX—[WHOLE NUMBER, CLXXX.]

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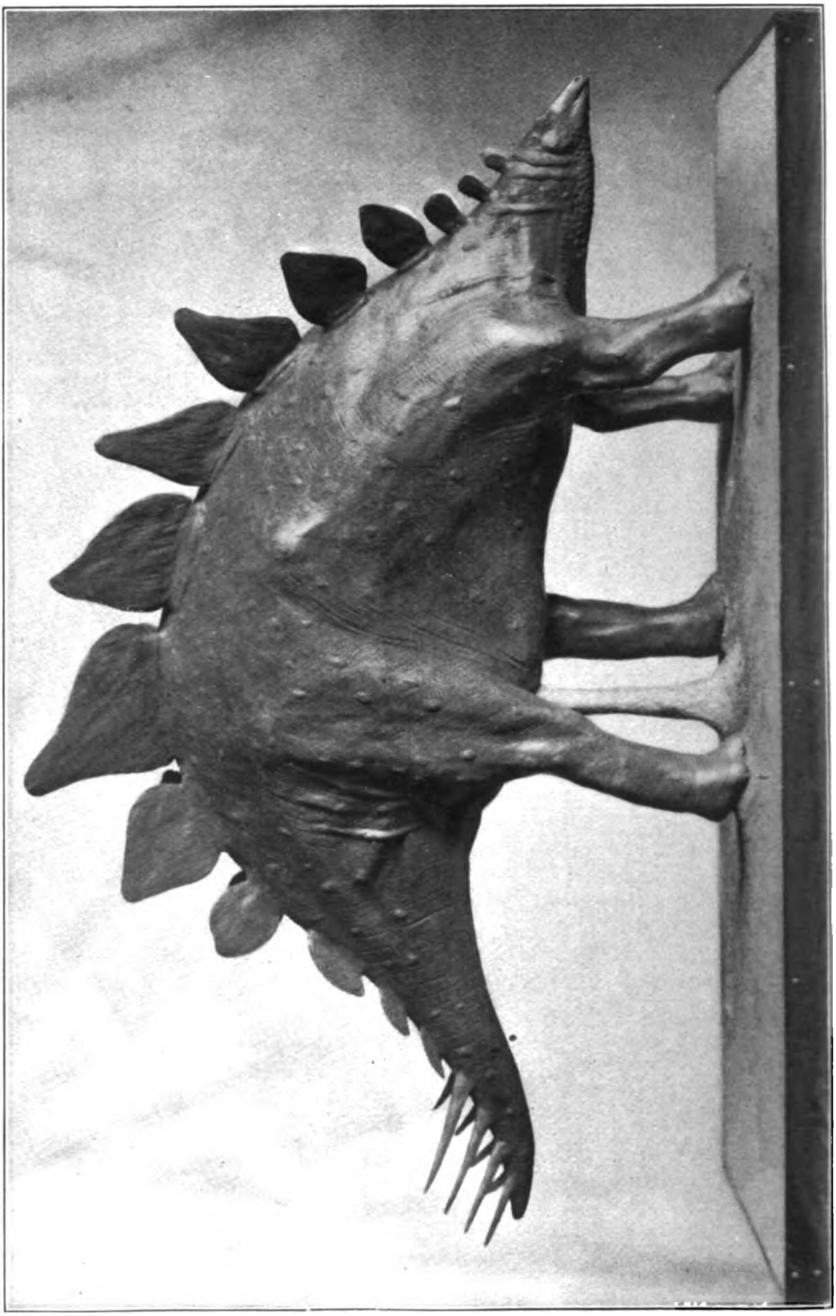

Model of *Stegosaurus ungulatus* based upon the mounted skeleton. Right side. Modeled by R. S. Lull.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXIX. — *Stegosaurus ungulatus Marsh, recently mounted at the Peabody Museum of Yale University;* by RICHARD S. LULL. (With Plate II.)

[Contributions from the Paleontological Laboratory of Peabody Museum, Yale University, New Haven, Conn., U. S. A.]

CONTENTS:

Introductory.
I. The specimen.
II. The skeleton.
III. Armament.
IV. Central nervous system.
V. Restoration in the flesh.
VI. Measurements.
VII. Life conditions and relationships.

THERE has recently been mounted at Yale University an almost perfect example of the armored dinosaur *Stegosaurus*, in many respects the most grotesque reptile the world ever saw. The interest lies not only in this, but in the fact that, while well known in literature owing to the masterly restoration upon paper by Professor Othniel C. Marsh, this reconstruction constitutes the first actual assembling of the bones in their proper relationships with, as usual, a somewhat different result from the generally accepted conception of the animal.

The genus *Stegosaurus* was first described by Professor Marsh in this Journal in 1877, the description being based upon the skeleton now mounted. Repeated articles by Marsh added to our knowledge of the creature until, in 1891, the first attempt was made to restore the animal on paper with the wonderfully accurate results attained by Marsh in so many similar drawings. Some errors naturally creep in when one is working entirely in one plane of space. These the actual mounting of the skeleton bone by bone alone can rectify.

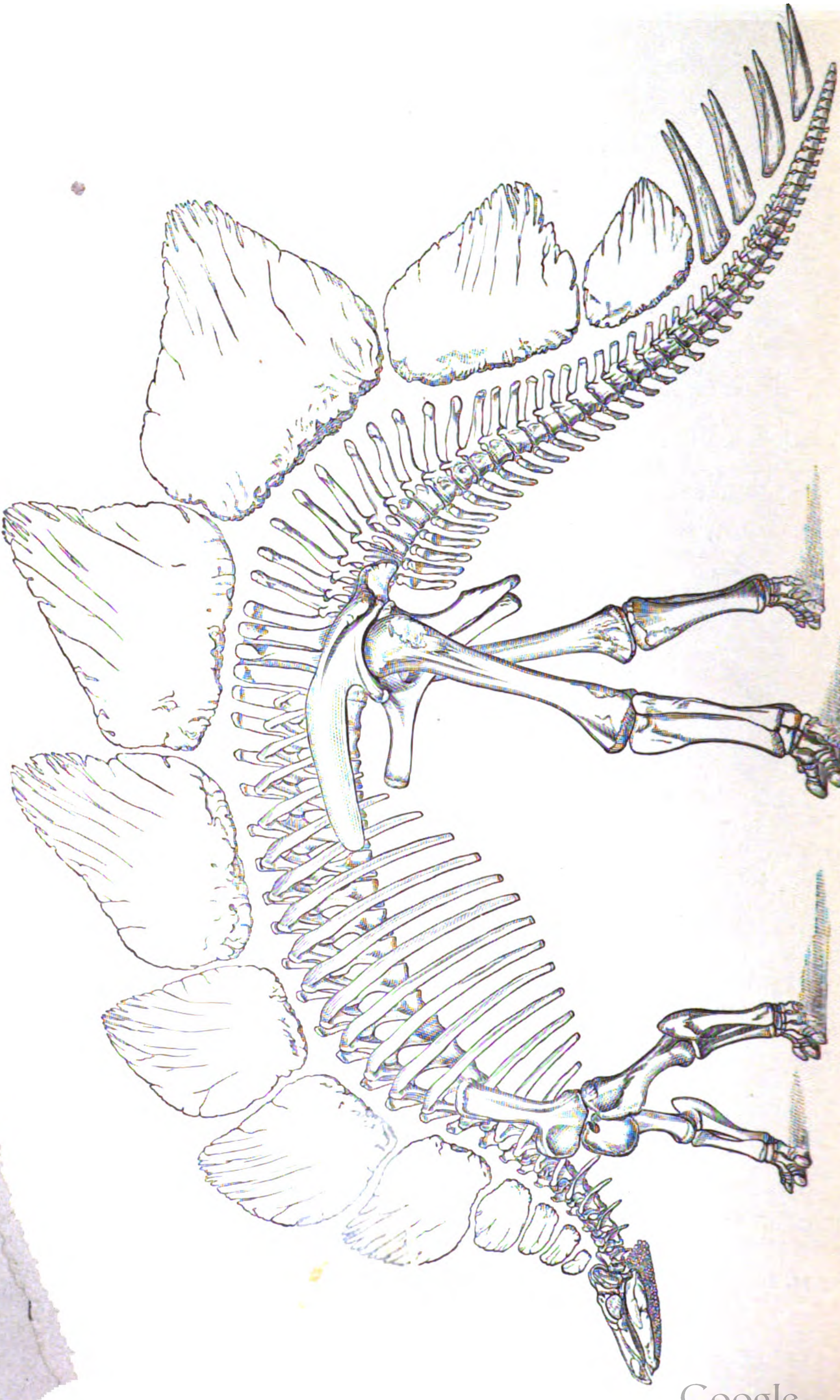

Fig. 1. Restoration of *Stegosaurus ungulatus*. After Marsh. 1/80 natural size.

I. *The Specimen.*

The mounted animal is a combination of two supplementary individuals which together constituted the cotypes of Marsh's original description of *Stegosaurus ungulatus*. They bear the catalogue numbers 1853 and 1858, and contain but little duplicate bone. These two animals were of nearly equal size, coming from near-by localities of apparently the same geological level in Como Bluff, Wyoming.

Fig. 2.

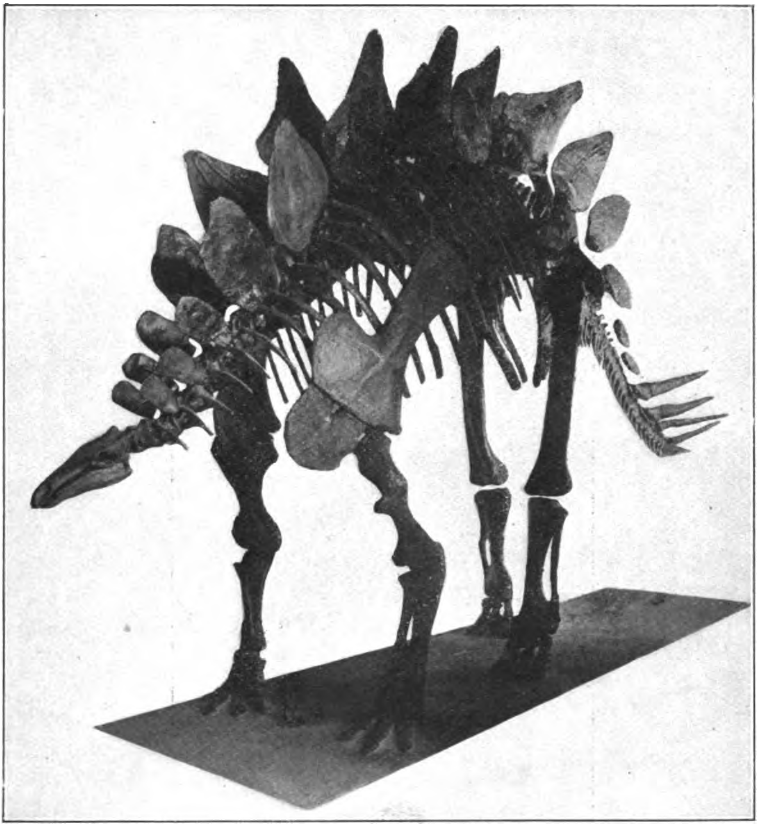

Fig. 2. Mounted skeleton in Peabody Museum, Yale University. Oblique front view.

[Owing to the limitations of the exhibition hall a side view of the skeleton could not be photographed. The correct proportions of the animal, here much foreshortened, can be seen in the frontispiece.]

In the year 1887,* however, Professor Marsh removed the specimen No. 1858 from the species *S. ungulatus*, making it the holotype of a new species, *S. duplex*. The specific distinctions, as the author gave them, lay entirely in the sacrum,

Fig. 3.

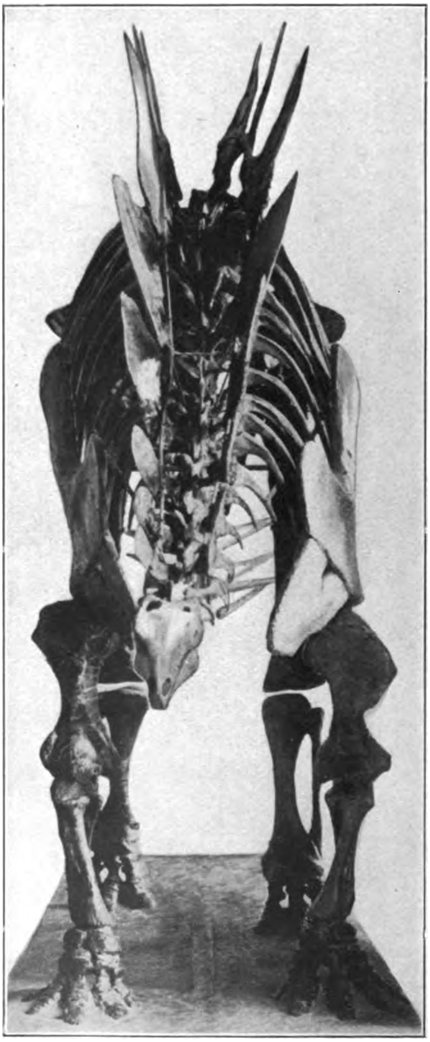

Fig. 3. Mounted skeleton. Front view.

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* This Journal (3), xxxiv, p. 416.

the distinguishing characters being that "In this species [*duplex*] each vertebra supports its own transverse process, or

Fig. 4.

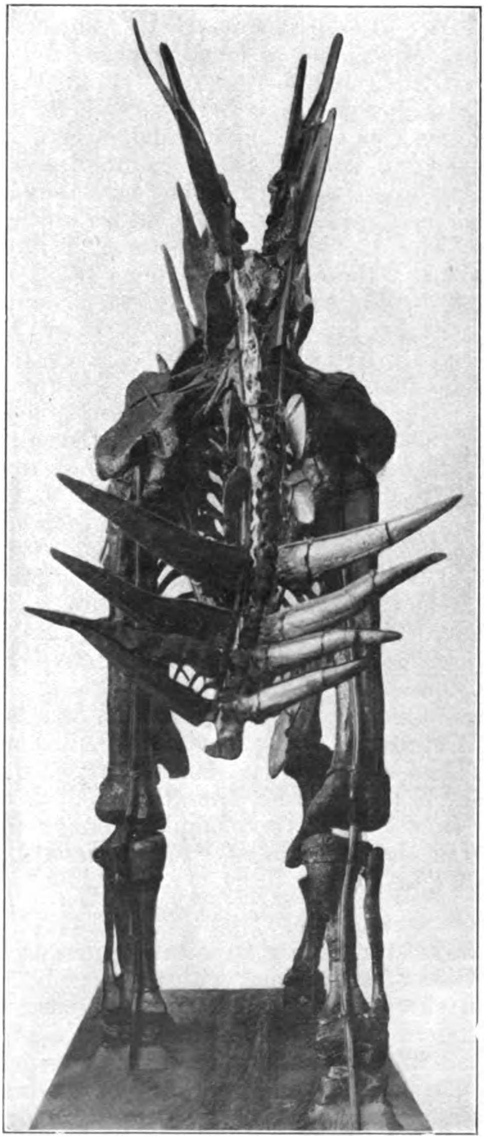

Fig. 4. Mounted skeleton. Rear view.

rib, as in the *Sauropoda*, while in the *S. ungulatus* the sacral ribs have shifted somewhat forward, so that they touch, also, the vertebra in front, thus showing an approach to some of the *Ornithopoda*." The specimen No. 1853 contains no sacral parts except the ischia; the above contrast being made, therefore, not with the other original type of *S. ungulatus*, but with an entirely new sacrum of a much younger individual (No. 1857) arbitrarily referred to that species. In this specimen, the sacral ribs are by no means as robust as in the older animal representing the type of *S. duplex*, and even in the latter a bearing of the rib against the preceding centrum may be observed. In other words, the difference is merely one of degree, which may readily be accounted for on the ground of relative age. The distinction in the form of the ischium of the type 1853 and those of the specimen 1858, which Marsh removed to *S. duplex*, is slight, the difference being mainly in a greater robustness especially in the distal end in the latter, which may readily be an age, sexual or even an individual variation. The two individuals embraced in the mount were much alike, as far as one may judge, differing mainly in proportions, No. 1853 being slightly longer and slenderer of limb. The above evidence was submitted to Professors Osborn and Williston and to Messrs. F. A. Lucas and C. W. Gilmore, the question being as to the advisability of combining the specimens in a single mount. The unanimous conclusion was that the validity of the species *S. duplex* was not proven, as the specific characters mentioned could not be contrasted with those of the remaining type of *S. ungulatus*, and that one was abundantly justified in referring the so called type of *S. duplex* back to its former status as a cotype of *S. ungulatus*, and, further, in combining the two supplemental cotypes in a single erection to represent the species and genus as originally described. Thus the skeleton stands, a few missing bones being modeled in plaster either from their fellows of the opposite side or from another very complete though smaller specimen known in the museum as "*Stegosaurus Y*," catalogue number 1856.

II. *The Skeleton.*

Some of the most notable anatomical features are the remarkable proportions of the animal with the sharply arched vertebral column, short neck, small head, lank, narrow body and extremely long limbs. The tail, which did not droop abruptly as represented in all previous restorations, was evidently held high above the ground and gives evidence, especially in its posterior half, of extreme sinuous flexibility, and, armed as it was with sharp-edged plates and spines, was the principal weapon of offense and defense against the sanguinary carnivores of that day.

The great power of the fore limbs is at once evident from the size of the scapular arch, the immense rugosities of the humerus and the development of the olecranon process implying a somewhat bent, easily flexed limb excelled only by the huge-headed dinosaur *Triceratops.*

The hind limbs, on the contrary, while powerful, were pillar-like, as the straight shaft and character of the knee joint give positive evidence. The fourth trochanter of the femur, so prominent in bipedal dinosaurs, is lacking, though the origin of the caudo-femoral muscle is nevertheless distinctly indicated. The loss of this trochanter together with the slight development of the pubic peduncle of the ilium precludes the possibility of a bipedal gait, though doubtless *Stegosaurus* is derived from a bipedal ancestry, quadrupedalism being secondarily acquired as in the Ceratopsia, owing to the immense weight of the creature's armament.

The vertebræ are unique in the curious upward prolongation of the neural arch and spine, the transverse processes and zygapophyses being borne high upon the latter, thus producing not only a very rigid back when subject to vertical strains but also raising the ribs and thus increasing the lung and visceral capacity of the body very materially without adding to its breadth. The whole character of the vertebræ and ribs, the latter being T-shaped in cross section near their proximal end, thus giving great stiffness and a broad bearing surface with the minimum of weight, is a wonderful adaptation for bearing the great dermal plates with which the back was adorned.

The feet are large as though to support the creature's weight on yielding soil, the hand evidently possessing five, while the foot bore three, well-developed digits. The semi-digitigrade feet were doubtless enclosed in a fleshy mass as in the modern elephants, while the external indications of the digits were mainly the hoof-like nails.

The body is extremely lank and the hips narrow, the breadth across the deltoid crests of the humeri being the greatest diameter of the animal's frame.

The dentition in common with that of other predentate dinosaurs, except *Hypsilophodon*, is confined to the rear portion of the jaws, the anterior part of the mouth being entirely toothless, very small, and probably ensheathed in a horny cropping beak. The dental battery, while of the same general type as that of *Camptosaurus* or *Iguanodon*, is very imperfectly developed, as the teeth are small, weak structures with crenulated margins and entirely invisible from the outside of the skull and jaws when closed, implying a food of a very yielding character which did not require the forcible mastication of that of *Iguanodon* or more especially of the late Cretaceous

Trachodon, in which the powerful dental battery of 2,000 teeth reaches its highest perfection.

III. *Armament.**

The exoskeleton of *Stegosaurus* included five types of structure, of which the first consists of small rounded ossicles found in one instance in position beneath the throat. The known armor of the back consisted of four distinct forms of plates in each of which the dorso-ventral diameter is enormously developed, and often the antero-posterior one as well, instead of a normal horizontal expanse, the result being the production of huge upstanding plates arranged in pairs on either side of the median line of the neck, trunk, and proximal part of the tail, while immense bony spines, possibly varying in numbers with the different species, were borne on the distal end of the latter. The plates are differentiated in that those borne upon the neck are short in fore and aft diameter but with a heavy base divided longitudinally by a depression which was borne astride the transverse processes and cervical ribs. The trunk plates increase rapidly in dimensions to a maximum size of $71 \times 66^{\text{cm}}$ ($=28 \times 26$ inches) and a weight of 40 pounds for the pair borne over the pelvis. Here the base was thick and rugose but without the longitudinal cleft. These plates were borne above the transverse processes and the proximal portion of the ribs until the sacrum was approached with its widely expanded neural spines to which the weight was transferred, the two rows of plates approaching each other more nearly than in the more anterior region.

This same type of plate, though with a base somewhat shortened and at the same time much broader, was borne over similar neural spines on the anterior third of the tail. Here the character of the neural spines abruptly changes, the broadened summits being lost and the whole spine very much reduced in height. This point, which marks the beginning of the aggressive, flexible portion of the tail, marks also an abrupt change in the character of the plates, which are now sharp-edged, pointed and bent backward, the base being embedded in the muscles between the neural spines and the vertebral centra. The sharp-edged plates, of which there are three pairs, are followed by four pairs of long spines similarly attached and pointing outward and backward at a decided angle. The longest of these is 25 inches and its present weight 14¼ lbs.

The character of the surface of the thin expansion of the plates, which doubtless represents the hypertrophied median

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* Lull, this Journal (4), xxix, pp. 201–210, figs. 1–11, 1910.

FIG. 5.

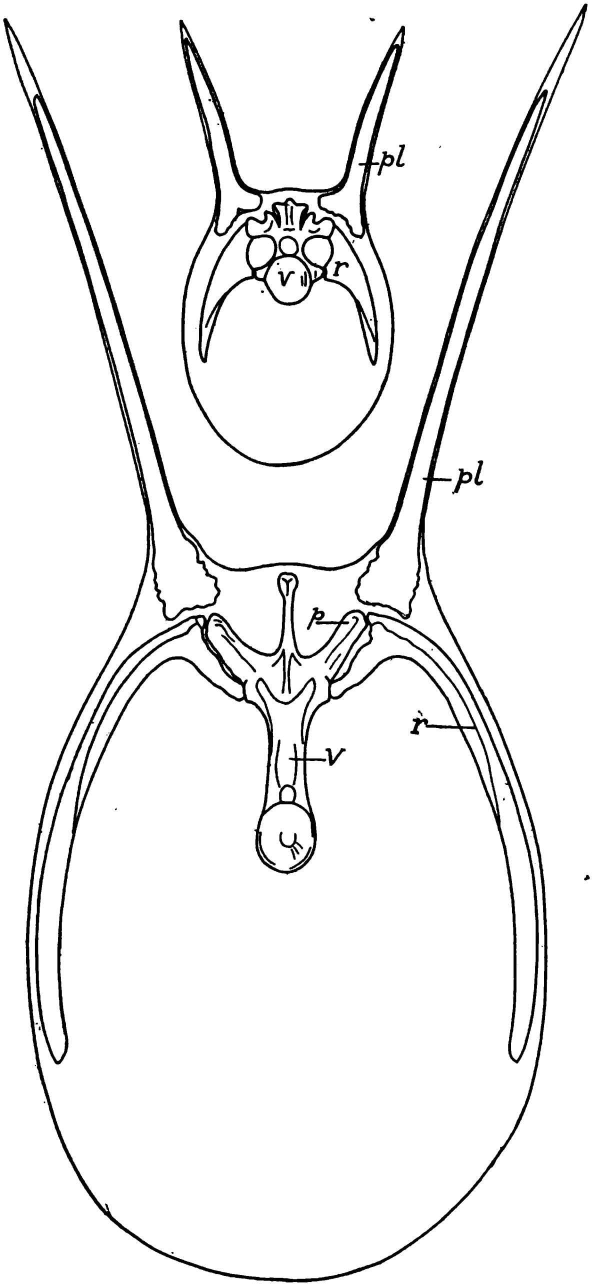

FIG. 6.

FIG. 5. Section of neck. After Lull. *pl*, plate; *r*, rib; *v*, vertebrum.
FIG. 6. Section of trunk. After Lull. *p*, transverse process; other letters as in fig. 5.

keel such as one sees in the crocodile and in other armored dinosaurs, and of the spines as well with deep blood-vessel impressions, implies a close-fitting horny integument which must have extended some little distance beyond the limits of the bone. The character of the base in both plates and spines, while indicating no articular connection with the underlying endoskeleton, nevertheless gives evidence of a firm cushion of

Fig. 7.

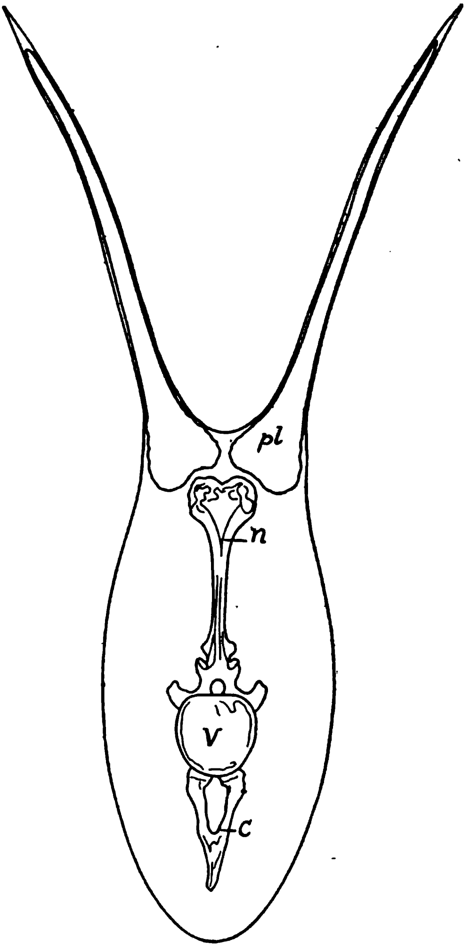

Fig. 7. Section of the proximal part of the tail. After Lull. c, chevron; *n*, neural process; other letters as in fig. 5.

cartilage of special erecting muscles, and of great thickness of the skin.

There are isolated, highly rugose ossicles, doubtless of dermal origin, associated with the skeleton, which cannot be placed with any degree of assurance, but which may have been scattered somewhat at random over the skin or concentrated at especially vulnerable portions of the body.

FIG. 8.

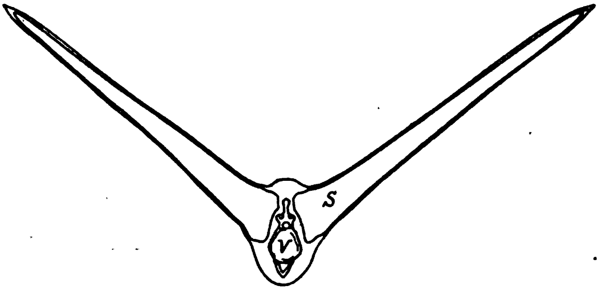

FIG. 8. Section of the distal part of the tail. After Lull. *s*, caudal spine; other letters as in fig. 5.

IV. *The Central Nervous System.*

One of the most remarkable features of this unique reptile lies in the form and proportions of the central nervous system as shown by internal casts and measurements of certain regions of the neural canal.

The brain is remarkable for its extremely small size, the entire cranial cavity, with a length of $1 \cdot 05^{cm}$ and a width of $0 \cdot 30^{cm}$, displacing but 56^{cc} of water and having an estimated total weight of but 2½ oz. The total weight of the animal must have exceeded that of the greatest of living elephants, the brain of which averages eight pounds or over fifty times the weight of that of *Stegosaurus.*

In comparing the relative potential intelligence of the two, one has also to bear in mind the great preponderance of the cerebrum over the other parts in the elephantine brain, while in *Stegosaurus* the cerebrum constitutes hardly more than a third of the entire brain weight. The stegosaur brain has a very large olfactory portion, small cerebellum, large medulla, and a hypophysis which is remarkable not only for its size but also for the peculiar shape. The sense of smell was apparently as well developed as may have been that of sight; the auditory sense I am not yet prepared to discuss.

Passing backward along the neural canal, one finds two enlargements: one at the fore limbs, the brachial enlargement, and the other within the sacrum. In the former, for a space of about four vertebræ, the neural canal, after an average width of $0\cdot25^{\mathrm{cm}}$, increases to $0\cdot38^{\mathrm{cm}}$ and to a proportionate height in the XIth vertebrum.

The neural canal in the sacrum is of startling dimensions, having a maximum enlargement of $1\cdot14^{\mathrm{cm}}$ and a greatest width of $0\cdot95^{\mathrm{cm}}$, and displaces nearly 1200^{cc} of water, thus giving it a mass more than twenty times that of the brain.

The brachial enlargement was the seat of the innervation of the powerful fore limbs, while that of the sacrum was mainly the reflex and coördinating center for the control of the mighty muscles of the hind limbs but more especially of the powerful, active and aggressive tail which constituted the principal means of defense.

FIG. 9.

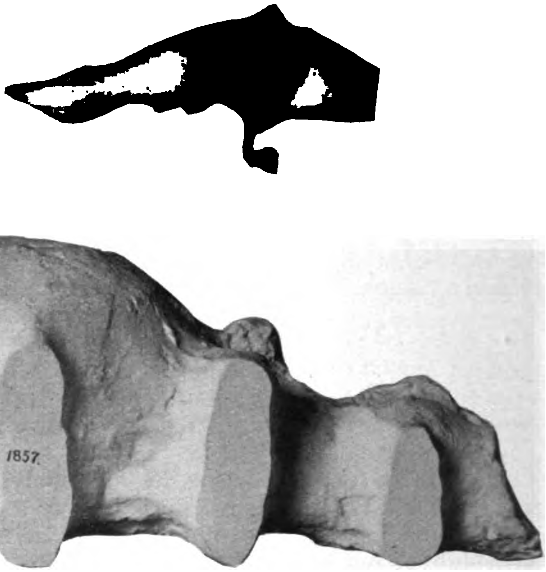

FIG. 9. **Casts of cranial and sacral cavities, showing proportions of brain to sacral enlargement of the spinal cord. 1/3 natural size.**

V. *Restoration in the Flesh.*

Under the direction of Mr. F. A. Lucas, Curator-in-Chief of the Museum of the Brooklyn Academy of Arts and Sciences and formerly of the U. S. National Museum, two restorations were made by the artist, Charles R. Knight. Of these, the first was a drawing published by Lucas in 1901 in his book.

"Animals of the Past," and again in the Smithsonian Report for 1901, Plate IV. The second restoration is a statuette one-tenth linear dimensions. In the drawing, the plates along the back were placed opposite to each other in pairs and the tail bore four pairs of spines, whereas in the later model the plates alternated and the pairs of spines were reduced to two. The apparent evidence for the alternation of the plates is offered by a specimen in the collection of the U. S. National Museum, in which they are preserved in the rock in the alternating position and in the fact that those of the opposite sides differ materially in shape and size. This Lucas still thinks conclusive, in spite of the fact that no known reptile has alternating dermal scutes, and that the probabilities are that the one row of the plates, as preserved in the matrix, has shifted forward or backward during maceration or in the subsequent movement of the rocks, as an oblique crushing of fossil bones is a very familiar phenomenon. The disparity in size and shape of the two plates of a pair is not surprising when one considers that the entire hypertrophy of the plate is in a sense abnormal and is comparable to the growth of the antlers of deer, notably the caribou, of which those borne by a single individual are rarely if ever precisely similar in size, weight, form, or even in the number of points.

The reduction of the number of caudal spines was also due to the evidence offered by two other specimens, also in the U. S. National Museum, with thespines *insitu.* The type of *Stegosaurus ungulatus*, however, shows four pairs and no further evidence of the duplication of bone, so that it is evident that they all belonged to one individual. It would seem, therefore, as though the number both of spines and plates may well have been a specific character if not an individual or possibly sexual variation.

During the erection of the Yale specimen, an admirable opportunity was offered for another model of which I have taken advantage, this time using a scale of one-fifth to reduce still further the margin of error. (Fig. 10. See Plate II.) The model is based not alone upon the proportions and positions of the various bones as in the mounted skeleton, but also upon studies of the individual bones made with a view of plotting thereon the attachments of the various skeletal muscles of the body and limbs. In this work, a small alligator was dissected and for comparison a specimen of *Sphenodon* (*Hatteria*) as well. I was also aided by the admirable work of v. Huene on the musculature of *Plateosaurus erlenbergiensis* (Die Dinosaurier der Europäischen Triasformation, Jena, 1908) as well as by Haughton's work on the muscular anatomy of the crocodile. One side of the model, the left (fig. 10), shows the superficial

Fig. 10.

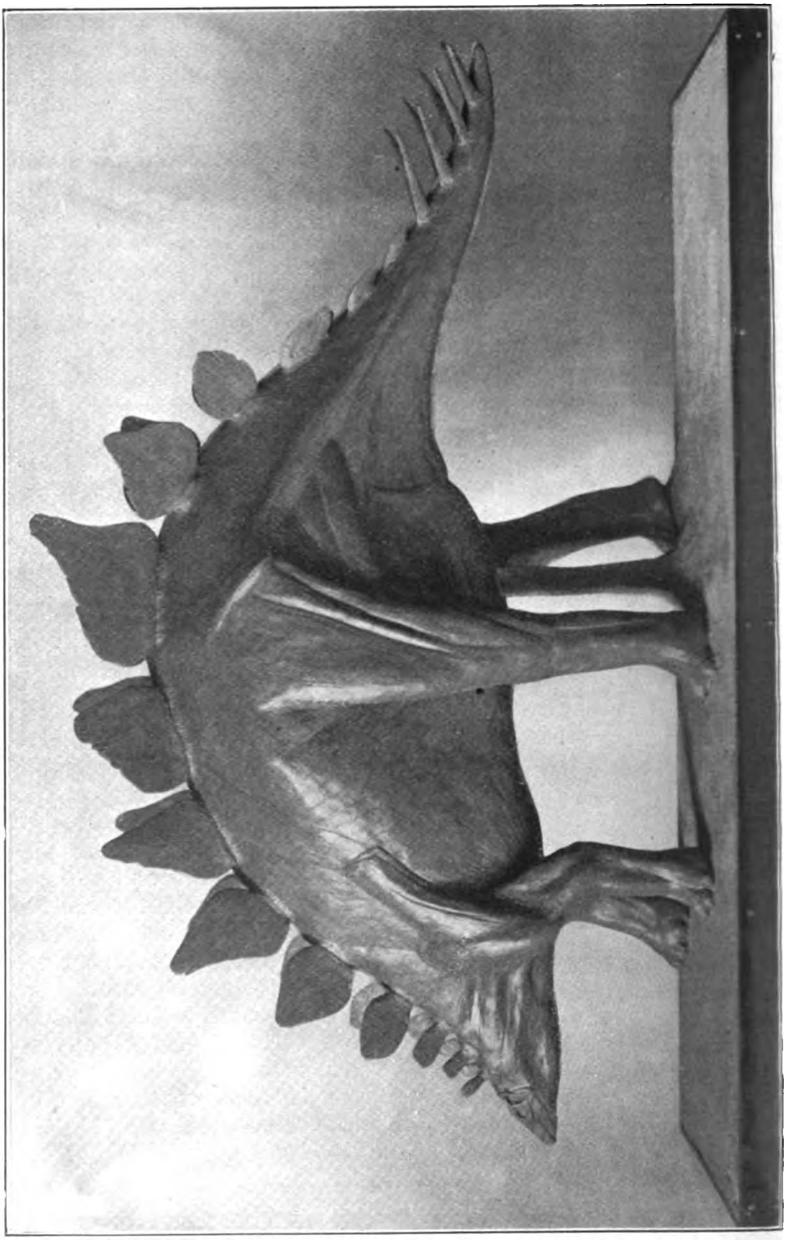

Fig. 10. Model of *Stegosaurus ungulatus*, based upon the mounted skeleton. Left side bereft of the integument, showing the superficial musculature. Modeled by R. S. Lull.

musculature of the body, the outlines of both ilium and scapula being indicated as landmarks and also the skull and the dermal plates, the latter bereft of their outer sheath of horn. The immense power of limb, neck and especially of the tail is shown, together with the slips of dermal muscle which stiffened the armor in time of stress, such as are seen beneath the scutes of the alligator. The right side of the model is clothed in the skin, which is indicated as of a leathery, elephant-like texture, with the shield of throat ossicles, as well as the scattered ones over the entire frame.

The gape of the mouth is represented, as in my previous models of the Ceratopsia, as extending but a short distance back, to the point where the dental series begins, owing to the necessity of muscular cheeks on the part of a masticating herbivorous form, in order to retain the food in the mouth. The gape thus includes only the prehensile part of the mouth, which is very small as compared with the vast body bulk which the creature is forced to sustain.

VI. *Principal Measurements.*

Length between perpendiculars	19 ft.	5 in.
“ of tail between perpendiculars	8 “	8 “
Height of sacrum	9 “	11 “
“ highest plate	11 “	10½ “
“ muzzle	3 “	4 “
“ tail tip	4 “	1½ “
Width of hips	3 “	5½ “
“ shoulders	3 “	10½ “
“ chest	3 “	8½ “
Height of shoulder	4 “	4 “
“ elbow	2 “	7½ “
“ hip	7 “	6 “
“ knee	3 “	3½ “

Present weight of the fossil skeleton, 1917 lbs.
Estimated live weight, between 7 and 10 tons.

VII. *Life Conditions and Relationships.*

The genus *Stegosaurus* is confined exclusively to the Morrison formation, upper Jurassic or lower Cretaceous of Wyoming, U. S. A., strata of nearly equivalent age to those of the European Wealden. The character of the environment was probably similar to the conception offered by Hatcher, who believed that the Morrison beds were deposited “over a comparatively low and level plain which was occupied by an interlacing system of river channels. The climate was warm, and the region was overspread by luxuriant forests and broad savannas * * * conditions doubtless similar to those now found about the mouth of the Amazon and over some of the more elevated plains of western Brazil." In spite of the numerous remains of plant-feeding animals, the actual relics of fossil plants are relatively few, nor does the sediment in which these remains are found give other evidence of abundant vegetation. Hatcher's inference of "luxuriant forests" is, therefore, as yet unproved by direct evidence.

The water areas, as has been shown,* were doubtless the dwelling places of the huge contemporaneous Sauropods, while *Stegosaurus* was terrestrial and possibly frequented the forests in search of the tender but luxuriant vegetation upon which it browsed. It may well be that the extreme relative narrowness was an adaptation to forest conditions and afforded ease of passage between the trunks of the tree ferns, conifers, and other vegetation of that day. *Stegosaurus* is rarely found entombed with sauropod dinosaurs, but, on the contrary, is often found isolated or in company with the bipedal unarmored herbivorous *Camptosaurus*, the nearest equivalent of the European *Iguanodon*, and with the fleet *Dryosaurus;* and of carnivores, the agile *Cœlurus* and the blood-thirsty *Allosaurus*, which was probably its greatest enemy.

I imagine much of the bizarre character of the armor of *Stegosaurus* was due to the over-specialization accompanying racial old age, but it was nevertheless in many respects admirably adapted to meet on a more or less equal footing the huge well-armed carnivore last mentioned. It would seem as though *Stegosaurus*, instead of presenting his front to the enemy, turned the rear, possibly crouching low in front as the crocodile does, and, with vigorous sweeps of the terrific tail, impaled the exposed ventral portion of the bipedal carnivore upon the caudal spines and sharp-edged plates.

The long hind limbs imply a rather rapid progression, while the powerful fore limbs were not only for locomotor purposes but for rapidly pivoting the body to prevent either a frontal or flank attack.

Of the evolutionary history of *Stegosaurus*, we know but little. It seems, however, to have been a migrant from Europe, having its nearest relative in *Omosaurus* (*Dacentrurus*), remains of which are known as far back as the Dogger (Bathonian) of England.

In *Omosaurus durobrivensis* from the Oxfordian of England, which I studied this summer in Cambridge and in the British Museum of Natural History, I find what may readily be a direct ancestor of the American types. The plates and spines are present, and, in every respect, the older animal differs only in being of a more generalized character. On the other hand, *O. armatus* of Owen, from the Kimmeridgian, though nearer *Stegosaurus* in time, is less like it than is its predecessor in the rocks. *O. armatus* would seem, therefore, to belong to a different phylum, in many respects more conservative than the true stegosaurs.

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* Lull, Dinosaurian Distribution, this Journal, xxix, p. 10, 1910.

That *Stegosaurus* belonged to the predentate dinosaurs and to the armored Stegosauria, is certain. It is not, however, in the direct line of descent, but rather an over-specialized side branch, which was apparently totally blotted out after Morrison time, despite the fact that most of its associates, except the Sauropoda, lived on.

The spinescent character of *Stegosaurus* is of course indicative of racial senility, but the modernizing of the flora and the restriction, doubtless, of the special food plant to which the feeble mouth armament was adapted, may have been the immediate cause of extinction.

The skeleton has been mounted under my direction by Head Preparator Hugh Gibb, assisted by W. S. Benton, and is a monument to their skill and industry.

ART. XL.—*The Use of Metallic Potassium in Determining Halogens in Benzol Derivatives*; by C. H. MARYOTT.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—ccxvi.]

A METHOD for the estimation of halogens in organic compounds by reduction with sodium and alcohol was described a few years ago by Stephanoff.* The writer recently attempted to use this method in determining chlorbenzol, but the results obtained were very irregular and unsatisfactory. Before enough sodium had been added to effect complete reduction, the liquid became pasty owing to the separation of sodium ethylate, and this localized and greatly hindered the action of the sodium. By increasing the amount of alcohol above that recommended by Stephanoff, the sodium ethylate could be kept in solution, but the large volume of liquid retarded the reduction, and thus increased both the time and the amount of sodium required. In all cases the results of the analyses were low.

A failure to obtain satisfactory results with Stephanoff's method has likewise been reported by Bacon,† who, however, devised a modification of the method, in which accurate results were obtained by heating the mixture for an hour after the solution of the sodium, thus utilizing the action of the sodium ethylate upon the halogens. Bacon's method was not tried by the writer, as the article cited came to his attention after the completion of the experiments described below. The long time required, about two hours, would seem to be a disadvantage, and the fact that certain of the benzol halogen derivatives such as monochlor- and monobrombenzol are attacked but little, if at all,‡ by boiling with sodium ethylate, a possible source of error in the method.

The use of potassium instead of sodium as a means of obtaining a more rapid reduction was suggested to the writer by Professor R. G. Van Name, and upon trial proved to be a great improvement. As the action of potassium upon alcohol is very energetic, a mixture of one volume of 98 per cent alcohol with two of thiophene-free benzol was employed. The presence of thiophene had to be avoided to prevent the formation of potassium sulphide, which would interfere in the subsequent estimation of the halogen. The reduction was carried out in an Erlenmeyer flask, and very little heating was required so that a plain glass tube about 50^{cm} in length, without water cooling, served as a condenser.

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* Ber., xxxix, 4056, 1906. † Jour. Am. Chem. Soc., xxxi, 49, 1909.

‡ The writer boiled monochlor- and monobrombenzol in a concentrated solution of sodium ethylate for three hours, but failed to get any test for halogens upon acidifying and adding silver nitrate. Bacon states in his article that he was unable to convert monobrombenzol into phenetol by heating with sodium ethylate, although 25 per cent of the chlorine was removed from hexachlorbenzol by the same treatment.

The test analyses given below were carried out as follows: The substance was weighed out in the Erlenmeyer flask, $10–15^{cc}$ of the alcohol-benzol mixture added, and the potassium, in small pieces, gradually dropped in through the tube. The weight of potassium required was about ten times* that called for by the equation

$$C_6H_5Cl + 2K + C_2H_5OH = C_6H_6 + KCl + C_2H_5OK.$$

A small amount of potassium ethylate usually separated out during the action of the metal, but seemed to have no bad effect upon the reduction. After the action had become less vigorous, about 2^{cc} of alcohol were added, the flask carefully heated and gently shaken from time to time until the potassium was all dissolved. The contents were then shaken with water, the water layer acidified with nitric acid, and the halogen precipitated and weighed as the silver salt. The use of Volhard's volumetric method in estimating the halogens, as done by Stephanoff and Bacon, would, of course, have been feasible, though somewhat less accurate. The time required for an analysis, exclusive of weighings, was about twenty-five minutes.

A series of analyses gave the following results:

CHLORBENZOL, 31·52 per cent Chlorine.

	Weight taken grm.	Per cent of chlorine found	Per cent error
(1)	·4036	31·62	+ ·1
(2)	·3533	31·46	— ·06
(3)	·4181	31·51	— ·01
(4)	·3278	31·44	— ·08
(5)	·4087	31·48	— ·04
(6)	·4245	31·53	+ ·01
(7)	·3324	31·52	± ·0
		----	
(8)	·3530	30·39	— 1·13

With the exception of No. (8) the agreement is satisfactory. The low result here is doubtless due to the use of an insufficient amount of potassium, as only six times that required by theory was added. The chlorbenzol was twice redistilled and that portion distilling between 131·5° and 131·7° used in the analyses.

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* Stephanoff's method calls for twenty-five times the theoretical amount of sodium.

BROMBENZOL, 50·92 per cent Bromine.

	Weight taken grm.	Per cent of bromine found	Per cent error
(1)	·3976	51·29	+ ·37
(2)	·3921	51·31	+ ·39
(3)	·3928	51·31	+ ·39

The results are very concordant but slightly high, probably due to impurity in the brombenzol, as the sample used was a commercial product once redistilled.

HEXACHLORBENZOL, 74·71 per cent Chlorine.

	Weight taken grm.	Per cent of chlorine found	Per cent error
(1)	·1301	75·39	+ ·68
(2)	·1190	75·15	+ ·44

The material used was Kahlbaum's product once recrystallized from hot benzol.

p-CHLORANILINE, 27·81 per cent Chlorine.

	Weight taken grm.	Per cent of chlorine found	Per cent error
(1)	·3081	27·93	+ ·12
(2)	·3456	28·00	+ ·19

To test the relative efficiency of sodium and potassium in their capacity as reducing agents, an analysis of chlorbenzol was carried out exactly as above described except that sodium (ten times the theoretical amount) was used in place of potassium. Only 84 per cent of the total chlorine was found.

It is therefore evident that potassium is very much more effective as a reducer than sodium, and is consequently better adapted for use upon such substances as the halogen substituted benzols, which belong to the most difficultly reducible class of organic halogen compounds. In the experience of the writer it gives, under the conditions outlined above, a complete reduction with the minimum expenditure of time and trouble.

Art. XLI.—*A New Genus of Peccaries;* by F. B. Loomis.

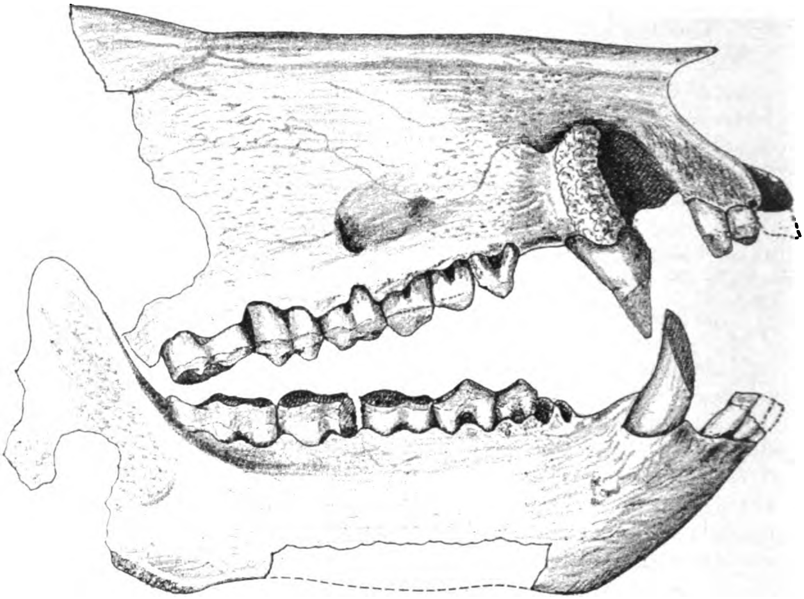
Since their introduction into North America in the Oligocene the peccaries have never been an abundant group, but have nevertheless held their own and progressed steadily though slowly toward their present structure. During the summer of 1908 the Amherst party found in the "breaks" about two miles southeast of the Raw Hide Buttes in Converse Co., Wyo., and in the sandstones of the Upper Harrison beds, the skull (lacking the brain case) and lower jaws of a peccary which is intermediate in development between Desmathyus of the Rosebud formation and the modern peccary, Tayassu. The specimen is No. 2047 in the Amherst College Museum and includes the muzzle in lower jaws, the dentition being complete except that upper incisor 1 and premolar 1 are wanting. The individual is old and the teeth well worn. The new form differs from the earlier genera and Desmathyus in having but 3/3 premolars, and is distinct from the modern type in that the third incisor is still retained; though the incisor series has already begun to assume modern character, in that the first incisor is greatly enlarged. With this form it will be seen in the table on page 384 that the series of peccaries is very nearly a perfect one.

Pediohyus ferus gen. et sp. nov.

The muzzle is moderately high with a straight or slightly convex upper boundary inclosing an ample olfactory chamber very like that of the modern peccary. The opening of the infraorbital foramen is well back, lying just over the front of the first molar. The alveolus for the upper canine is greatly swollen on the outside into a rough projecting tubercle. In front of this there is a correspondingly deep pit for the reception of the lower canine.

The first upper incisor is wanting but the greatly enlarged alveolus shows that it was of the modern type, broad and elongated and two to three times the size of the other incisors. Incisor 2 is less than half the size of the first, and has a simple blunt wedge-shaped crown. The third incisor is still smaller but by no means vestigial. Between it and the canine is a gap of some 20^{mm}, which represents the width of the pit for the lower canine. The upper canine is a powerful tooth but slightly bent backward, and approximately oval in cross section. The anterior face is beveled off with wear. It is hard to say what caused the wear as the tooth does not meet the lower canine, but use must have ground the major part of the tooth away.

Fig. 1.



Pediohyus ferus. Type specimen ½ nat. size.

There is no upper premolar 1, the interval behind the canine occupying 15^{mm}. The second premolar is small with a single primary cusp near the front and a smaller one behind. The third premolar is wider and has two anterior cusps which are higher and stouter than the small ones on the back of the crown. The fourth premolar is distinctly molariform, though distinctly smaller than any molar and having but three distinct cusps, the two anterior and the outer posterior one, the inner posterior cusp being replaced by a low ridge (very like a strong cingulum). All these premolars are much less progressive than the corresponding teeth in the modern Tayassu.

The molars have low quadratical crowns and have been so much worn that the details are not now clear. Each seems to have had four primary cusps, and the cingulum as well or better developed than in the recent genus.

The incisors of the lower jaw are simple and normal except that the third one is less reduced than in the recent peccary. The canine is a powerful tooth, which in the type specimen is much worn and beveled on the anterior face. The first premolar is wanting, the second being separated from the canine by a diastema of 23^{mm}. Judging from the alveolus, the tooth was small and simple. The two succeeding premolars are much larger, but in this specimen are too worn to admit careful description. The molars are low crowned, the third being provided with a large heel.

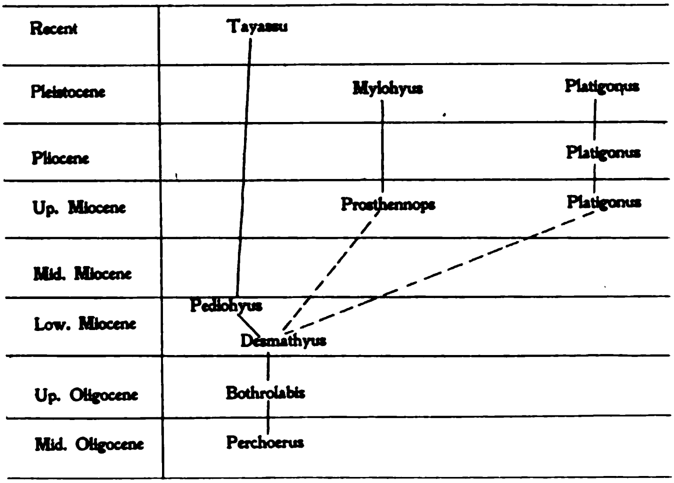
Measurements.

Length of upper dentition	170^{mm}
Width of incisor 2	8
Width of incisor 3	5½
Length of upper premolar series	35
Length of premolar 2	11
Length of premolar 3	11
Length of premolar 4	13
Length of molar series	58
Length of molar 1	19
Length of molar 2	19
Length of molar 3	20
Length of lower premolar series	41
Length of lower molar series	64

The following table shows the relative development of the dentition of the various genera of this Tayassuinae family or series:

	Age	Dentition	Incisors	Premolars	
Perchœrus	Mid. Oligocene White River	$\frac{3}{3}\ \frac{1}{1}\ \frac{4}{4}\ \frac{3}{3}$	Equal	All simple	No notch for lower canine. Skull rather brachicephalic.
Bothrolabis	Up. Oligocene John Day	$\frac{3}{3}\ \frac{1}{1}\ \frac{4}{3}\ \frac{3}{3}$	Equal	All simple	Notch for lower canine. Skull mesocephalic.
Desmathyus	Low. Miocene Low. Rosebud	$\frac{3}{3}\ \frac{1}{1}\ \frac{4}{3}\ \frac{3}{3}$	In. 1 enlarged In. 3 reduced		Notch for lower canine. Skull mesocephalic.
Pediohyus	Low. Miocene Up. Harrison	$\frac{3}{3}\ \frac{1}{1}\ \frac{3}{3}\ \frac{3}{3}$	In. 1 enlarged In. 3 reduced	P. 4 slightly molariform	Notch for lower canine. Skull mesocephalic.
Tayassu	Up. Miocene — Recent	$\frac{2}{3}\ \frac{1}{1}\ \frac{3}{3}\ \frac{3}{3}$	In. 1 enlarged In. 3 lost	P. 4 molariform P. 3 less " P. 2 " "	Shallow notch for lower canine. Skull mesocephalic.
Platigonus	Up. Miocene — Pleistocene	$\frac{2}{3}\ \frac{1}{1}\ \frac{3}{3}\ \frac{3}{3}$	In. 1 enlarged	Simple	2 or less transverse crests on upper premolars and molars. Skull mesocephalic.
Prosthennops	Up. Miocene	$\frac{2}{3}\ \frac{1}{1}\ \frac{3}{3}\ \frac{3}{3}$	Reduced	P. 3 and 4 molariform	Skull dolicocephalic.
Mylohyus	Pleistocene	$\frac{0-2}{3}\ \frac{1}{1}\ \frac{3}{3}\ \frac{3}{3}$	Vestigal or wanting	P. 2–4 molariform	Skull dolicocephalic.

From the above it will be seen that the various genera of peccaries represent three lines of development, a mesocephalic type beginning with Perchœrus and ending in Tayassu, a dolicocephalic type including Prosthennops and Mylohyus, and the aberrant genus of Platigonus. The series is distinctly an American one, appearing first and doubtless by migration from Asia during the lower Oligocene. A couple of species have been doubtfully referred to Hyotherium, and it was probably some primitive member of that genus which on reaching this side soon developed the peculiarities which separate the peccaries from the pigs. Life in a more open country might well have started the modifications which are especially along the line of slenderer build and speed. The following diagram may graphically indicate the general relationships of the known genera:



Beside these there are a few forms known only by fragmentary material, like Chænohyus, Leptochœrus, and Nanohyus, which cannot be placed in their relationships until more complete material is found.

Amherst College.

ART. XLII.—*The Geology and Topography of the Serra de Jacobina, State of Bahia, Brazil;* by JOHN C. BRANNER.

THE Serra de Jacobina, taken as a whole, is the most beautiful and most majestic mountain range in Bahia, and one of the finest in all Brazil. The range is known at different places by more than a dozen different names, these names, in accordance with the popular custom in the interior, being taken from the various cities, towns, villages, and estates situated along its base.

For the sake of geographic and geologic clearness it seems best to call the range as a whole the Serra de Jacobina, for that is the name by which it is most widely and most appropriately known in Brazil, though it is called the Serra de Saude in Barão Homem de Mello's Atlas do Brazil. The local names may well be left for the various high peaks in the range.

The profile given by Dr. Allen in Hartt's Geology and Physical Geography of Brazil, at page 310, gives an erroneous impression of the topography about the city of Jacobina. This impression has been further deepened by the other erroneous idea that there is one great mountain-range—the so-called Serra do Espinhaço of Eschwege—extending across this region.* As a matter of fact there are two very distinct ranges at and near Jacobina, to say nothing of others farther west, while, so far as the Serra do Espinhaço is concerned, a field examination of the topography and geology of the region lends little or no support to the theory of the existence of such a range in this part of the state of Bahia.

The southern extremity of the Serra de Jacobina is nearly three hundred kilometers on an air-line northwest of the city of Bahia. Its southern end is on the north side of Rio Jacuipe, just southeast of the village of Canna Brava, and some thirty-five kilometers south of the city of Jacobina. From this point it runs nearly due north past Jacobina, Saude, Campo Formoso, Villa Nova, and Jaguararý, and ends just west of the station of Jurema, on the Bahia and São Francisco railway—a total distance of 225 kilometers on a line. Though it widens considerably at some places, its average width is only about six or seven kilometers. The altitudes of the highest points in the range have not been measured. The writer has determined the altitudes of a few prominent peaks, but none of the peaks climbed by him was the highest. The highest peak ascended

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*** O. A. Derby. The Serra do Espinhaço, Brazil, Jour. Geol., xiv, 347-401. This article reproduces Dr. Allen's profile and sketch of the Serra do Tombador.**

is one called the Serra de Sant'Anna, ten kilometers north of the city of Bomfim. This peak has an altitude of 1100 meters above tide level (three aneroid measurements). There are considerably higher points in the range farther south in the vicinity of Saude, Jacobina, and Canna Brava.

Sections across the Serra de Jacobina made at different places differ but little from each other. Everywhere the rocks are conglomerates, quartzites, and talcose shales or schists with steep dips toward the east. Along the western base of the range these sedimentary beds rest upon granites or old eruptives, while on the east side also the granites and other crystalline rocks come close up to its base. The city of Jacobina stands at the western base of the Serra de Jacobina where that range is cut in two by the Rio Itapicurú. Near that city on the west side of the range the granites and old crystalline rocks extend westward from the foothills of the Serra de Jacobina to and up the slope of the Tombador range. It should be clearly understood that the Serra de Jacobina is entirely distinct from the Serra do Tombador, which is a parallel range some thirty kilometers west of Jacobina. The Jacobina range is formed of sedimentary beds, mostly quartzites, alternating with slates or schists, standing nearly on end, and is high, narrow, rugged and picturesque. The Tombador range is low, of even horizontal crest, made of nearly horizontal sandstones and quartzites that rest upon granites and form a vertical escarpment along the east face of the mountain, while on the west they dip gently westward and pass beneath the Salitre valley. The diagram given at page 337 of the article on the Serra do Tombador† shows the relations of these two mountain ranges to each other both topographically and geologically.

Fig. 1.

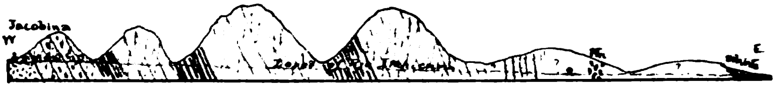

Fig. 1. Section along Rio Itapicurú at Jacobina where it cuts through the Serra de Jacobina.

The sections examined across the Serra de Jacobina are here given in more detail.

The city of Jacobina is at the parting between the granite area west of the Serra de Jacobina and the quartzites that form the serra itself. The actual contact between the two kinds of rocks is not exposed on Rio Itapicurú in the town. It is quite evident, however, that this contact crosses the middle of the city just west of the Conceição church, and close to the city jail. North of the city this parting comes out clearly in the vegetation. The bare quartzites are covered with a stunted growth of bushes, while the vegetation on the granites is more vigorous and abundant, and its color is of a brighter green. Along this west flank of the range toward the north one sees clearly the eastward dip of the sedimentary series forming the serra and the strike which is always parallel with the range itself. Immediately south of the Itapicurú near Jacobina the sandstones and quartzites near the contact are so jointed that one can hardly find a block a foot in diameter.

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† This Journal, vol. xxx, p. 335.

The influence of the rocks on the vegetation is noticeable south of the river. The "monte" or peak with the cross at its summit is just south of the city and 150 meters above it. The north end of this ridge is of green-stained, flinty quartzite conglomerate. The pebbles of these conglomerates are often as large as hen's eggs, and the metamorphism is so complete that the outlines of the pebbles are often obscure. A kilometer or so farther south along this same ridge pebbles 15 centimeters long are common. The fracturing or jointing of some of these conglomerates and quartzites is remarkable. Over some exposures there are three sets of parallel joint-planes intersecting each other with striking regularity at angles of thirty degrees, and breaking the beds into small angular blocks. Another striking characteristic of these basal conglomerates is that the well-worn pebbles of which they are composed are themselves made of quartzitic sandstones. In other words, these conglomerates are not derived from the underlying granitic rocks, but from an older series of sediments. Some sixty-five kilometers farther north the Rio Itapicurú cuts through the range, but this section was not examined by the writer.

Something more than a hundred kilometers north of Jacobina a good section of the Jacobina range is exposed near the town of Campo Formoso, where it is again cut by a stream, the Rio do Campo Formoso or da Agua Branca. At this place the mountain range as a whole is made up of four parallel quartzite ridges dipping eastward at a high angle. The hard beds of the series are quartzites very much like the so-called itacolumites of Minas Geraes, while the yielding beds are talcose schists. The town of Campo Formoso at the mountain's western base stands on granites, and the waters that unite at this place to form Rio do Campo Formoso flow almost exclusively from the granite area that forms the rolling country immediately west of the Serra de Jacobina. The plains that extend eastward and southeastward from the serra's eastern base are also of granites, mica schists, and other crystalline rocks, with here and there a quartzite ridge rising above the general level. The mica schists are exposed on the road about two and a half kilometers due south of Monte Tabor. The quartzites and other rocks of the Monte Tabor range, which is the easternmost member of the Jacobina range, all dip toward the southeast at a high angle.

About twenty kilometers northeast of Rio Agua Branca another section across the Serra de Jacobina was examined on and in the vicinity of the road between Villa Nova and Campo Formoso. The general structure on this road is shown in the accompanying section (fig. 3).

FIG. 2.

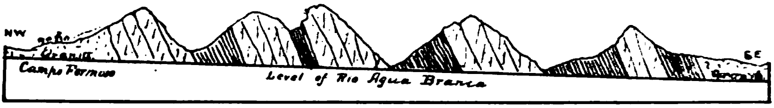

FIG. 2. Section across the Serra de Jacobina along Rio Campo Formoso or Agua Branca.

In this section the summit of the Morro da Mina has an elevation of 950 meters a. t. or 403 meters above the railway station at Villa Nova. A dip measured on Morro da Mina is 60° S. 40° E. magnetic. The rocks are the usual quartzites more or less decomposed at many places, and red and purple shales interbedded with them.

FIG. 3.

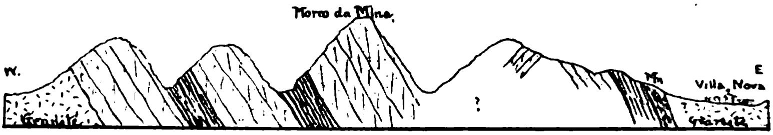

FIG. 3. Section across the Serra de Jacobina west of Villa Nova.

The next section across this range to which attention is called is west from the railway station of Jaguararý and twenty-five kilometers north of Villa Nova. The distance through the range at Jaguararý is about six kilometers on a straight line, and about nine by the trail. The drainage does not cut entirely through the range here as it does at Campo Formoso and Jacobina. The rocks exposed at and about Jaguararý are all granites. These granites are cut by the railway at several places south of the town, and they are well exposed in bosses from thirty to fifty meters across.

The serra at this place is made up of four quartzite ridges, the three parallel valleys being cut in talcose schists similar to those found in the other sections. The schists are also exposed on the plain between the easternmost quartzite ridge and the town of Jaguararý. Throughout the whole section the rocks dip eastward; one dip measured in the purplish quartzites of the eastern range was due east at an angle of sixty degrees.

West of the range the rocks of the plain are granites and gneisses and these rise more than half way up the western slope of the mountain. The actual contact between the sedimentary series and the crystalline series was not seen; those observed nearest the quartzites are soft cream-colored rocks that have the appearance of being composed of decomposed feldspars. Below these are laminated gneisses in an advanced stage of disintegration.

FIG. 4.

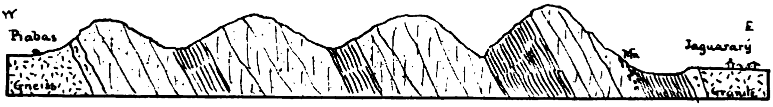

FIG. 4. Section across the Serra de Jacobina between Jaguararý and Piabas. Length of the section, ten kilometers.

At my request Mr. Roderic Crandall made a trip across the serra along the upper portion of the Rio do Poço Comprido, which cuts across the Jacobina range twenty kilometers north of Jaguararý. Mr. Crandall found the range at that place to be made up of four parallel ridges of quartzite whose beds dip north eighty degrees east at an angle of seventy degrees. Granites form the plains both on the east and the west sides of the serra. The structure is, therefore, the same as that shown in the other section across the range.

The examples given are enough to show the remarkably uniform structure throughout of the Jacobina range. They also show at all the points examined the granites, gneisses or other old crystalline rocks on both sides of the range. The relations of the granites on the west side of the range to the sedimentary series seems to be fairly clear: the form, continuity, and position of the parting suggest, if they do not positively prove, that the sedimentary series was laid down upon the granites. On the east side of the range, however, the contact between the granites and the sediments has not certainly been observed, and there is, therefore, more or less doubt about the relations of the sediments of the serra to the crystalline rocks of the plains to the east. Everywhere the four main ridges of the serra are of extremely hard quartzites, while the valleys are cut in soft talcose schists.

The following theories have been entertained in an attempted explanation of the facts thus far gathered in regard to the Serra de Jacobina:

I. The theory of a single synclinal fold having the two eastern members turned back so far that the beds have the same dip as the western ones. The relations would then be such as are suggested by the accompanying section.

Fig. 5.

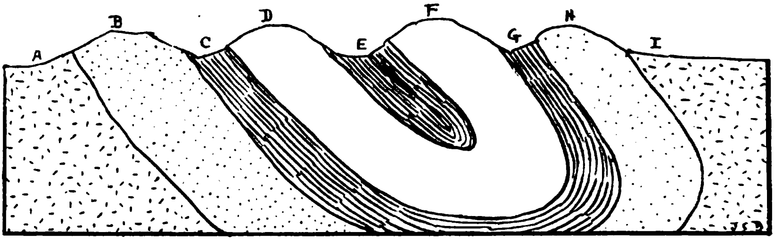

Fig. 5. Theoretical section to show the surface repetition of beds in a synclinal fold.

If this were the correct explanation of the structure of the range one should expect to find the ridges *B* and *H* to show such similarity in material and sequence of their beds as are commonly found in sedimentary deposits at similar distances from each other. The same would be true of ridges *D* and *F* and of the valleys *C* and *G*. At *E* one would expect to find a double thickness of a single bed or group of beds. To put it differently: starting at *E*, the axis of the syncline, one should find the same or nearly the same sequence of rocks in passing from *E* to *A* as he would in passing from *E* to *I*.

It cannot be said that the study of any of the sections examined across the range has been sufficiently critical to settle this point beyond question. The facts that appear to bear upon it, however, are mostly unfavorable to the theory of a synclinal fold. These facts are here given very briefly.

1. Along the eastern face of the range is a series of manganiferous schists or shales that is repeated on its western side at only one place, so far as seen, and that is at and north of the village of Brejão. The distance through the range on this theory, however, is large enough to diminish considerably the importance of this particular fact.

2. So far as is now known, the conglomerates of the western ridge of the range are not repeated in the eastern ridge. Here again the distance through the range may be urged against the probability of the similarity of the beds over so wide a zone.

II. The second theory is that of the repetition of the same beds by four parallel faults. This theory would require but one series of quartzite beds and an overlying series of schists or slates. Four parallel faults, as suggested in the accompanying figure, might yield the general structure of the range.

FIG. 6.

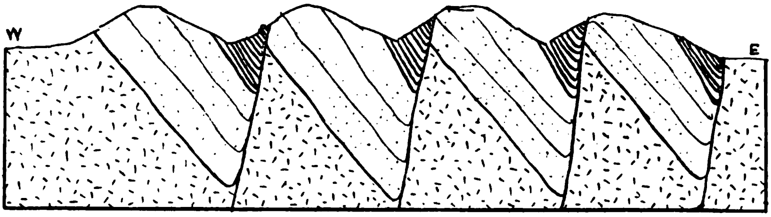

FIG. 6. Ideal section across the Serra de Jacobina on the theory of its having been formed by four parallel faults.

The chief objection to this theory is the great length of the range and its apparently uniform character throughout. It would be very remarkable to find four faults so evenly spaced for 225 kilometers and following each other in the curves made by the range throughout that entire distance.

A second objection is that the manganiferous shales or slates near Villa Nova and Jaguararý are not repeated in the valleys within the range as we should expect if the structure were produced by such a series of faults. Similarly the heavy conglomerates at the base of the series at Jacobina are not repeated in the easternmost ridge of the range.

FIG. 7.

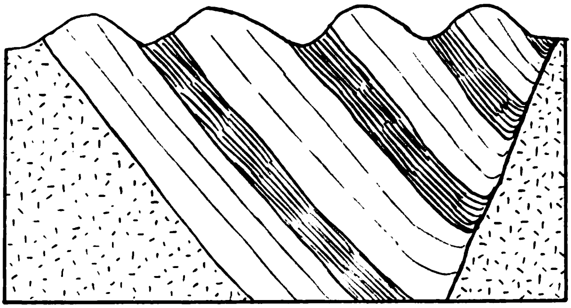

FIG. 7. Section across the Jacobina range on the theory of a single fault with the downthrow on the west.

III. The third theory is that of a single fault along the eastern face of the range, with the downthrow on the west and the subsequent denudation of the uplifted eastern side. According to this theory, the structure would be something like that shown in the accompanying figure.

There seems to be no special objections to this theory unless it be the great depth required for the theoretical single fault.

The remarkable fact that the great Serra de Jacobina is cut entirely in two at several places by streams flowing through steep-sided gorges will be discussed in a later chapter on the geography of the State of Bahia.

The following questions should be kept in mind by those who may hereafter have opportunities to study the geology of the Jacobina range:

I. Are there always four parallel ranges, or is this appearance misleading?

II. Is the Jacobina range of the same geologic age, and has it the same general history as the smaller quartzite ridges on the plains both east and west of the range, and mentioned in this Journal, Oct., 1910, p. 263.

ART. XLIII.—*On an Indirect Method for Determining Columbium and Tantalum*; by H. W. FOOTE and R. W. LANGLEY.

Introduction.

THE determination of tantalum and columbium in mixtures of their oxides has always been one of the difficult operations in analytical chemistry. The method for separating the two metals was devised by Marignac* and consisted in separating by crystallization the difficultly soluble potassium-tantalum fluoride from the more soluble columbium salt. This method, with various minor modifications, is still the one commonly used. The operations involved are tedious and the results are only approximate. Judging by our own experience, the method requires some practice before even approximate results can be obtained. The reason why the results are inaccurate is first, because the tantalum salt obtained is not quantitatively insoluble, so that tantalum is left in the filtrate with the columbium, and second, because of the tendency of columbium to crystallize to a limited extent with the tantalum double fluoride.

Two volumetric methods have been proposed, both depending on a preliminary reduction of columbium to a lower oxide and titration with potassium permanganate. By the first of these methods† columbium is reduced by zinc in strong hydrochloric acid solution, and titrated with potassium permanganate which has been standardized by means of a pure columbium salt. In the second method‡, columbium in a solution containing succinic acid is reduced by amalgamated zinc. Under fixed conditions, by this method, columbic oxide is reduced to the empiri caloxide $Cb_{20}O_{31}$, and can be titrated with permanganate.

The method of separation proposed by Weiss and Landecker§ will be discussed in the article immediately following this.

The low density of columbic oxide (4·552) as compared with the density of tantalic oxide (8·716) suggested that the composition of any mixture of the two could be deduced from its density, if the density of mixtures of known composition was first determined. The principle has been applied by Penfield and Ford‖ to the estimation of the proportions of tantalic and columbic oxides in stibiotantalite, assuming that the density of mixtures of the oxides is a linear function of the composition.

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* Archiv. des Sci. Phys. et Nat., 1866.

† Osborne, this Journal [3], xxx, 329, 1885.

‡ Metzger & Taylor, Zeitschr. anorg. Chem., lxii, 383, 1909.

§ Zeitschr. anorg. Chem., lxiv, 65, 1909.

‖ This Journal [4], xxii, 61, 1906.

The problem consisted in preparing various known mixtures of the two oxides under definite conditions and determining the densities of the mixtures.

Methods and Errors.

We first investigated the method to be used to determine the density. The mixed oxides as they are obtained in analysis are very fine powders. After some preliminary work the following method for determining density was adopted. The ordinary form of bottle pycnometer of 10^{cc} capacity was used. The stopper was carefully ground to fit, using fine carborundum powder. The capacity was redetermined from time to time, but it remained nearly constant. The unweighed material was finely powdered and placed in a small beaker half full of water. The water was boiled hard for a half hour by passing an electric current through a fine spiral of platinum wire suspended in the water, the powder being stirred up a number of times during the operation. The water could not be boiled in a beaker over a flame on account of severe bumping, as the powder settles rapidly. The boiling can be accomplished over a flame, however, if a rough platinum dish is substituted for the beaker and the liquid stirred continually. The contents of the beaker were cooled, most of the water poured off, and the residue washed through a funnel into the pycnometer with boiled water. Any powder on the neck of the pycnometer was washed down and the pycnometer filled to overflowing. Any powder or air bubbles floating on the top were swept off with a glass rod. Air bubbles did not usually adhere to the sides, but were always looked for and removed with a wire if present. The pycnometer was placed in a tank of water and kept at 20° C. for twenty minutes. The stopper was then inserted, the top quickly wiped off, and the whole dried and weighed at once. The contents were transferred to a platinum dish, evaporated to dryness, and ignited finally over a blast for five minutes. In transferring the contents of the pycnometer to the dish it was found that all loss could be avoided if the pycnometer were inverted over the dish and shaken slightly till the powder left the bottom. By then bringing the mouth against the side of the dish the mixture will run out quietly. Two or three rinsings with water are necessary. The pycnometer usually contained a trace of oxide sticking to the sides, which might weigh as much as two milligrams. It was therefore dried at 120° C. and weighed to determine the small amount of oxide. This method gave results which were entirely satisfactory for our purpose. The average difference between duplicates in forty determinations of density amounted to 0·22 per cent. This result includes several determinations in which the amount of material used was under one gram, which increased the percentage error considerably. When two grams or more of material were used, duplicates seldom disagreed by more than 0·15 per cent. To illustrate: the densities found for a mixture containing 90 per cent tantalic oxide were 8·103 and 8·078 when 1·5 grams were used. Upon repeating the experiment with 3·3 grams of material, the densities found were 8·090 and 8·092.

We next determined that the mixed oxides became constant in density after heating for an hour over the blast lamp. For this purpose a sample of the mixed oxides from a Branchville columbite was ignited over the blast lamp for an hour in a platinum crucible. The density was determined and the material then ignited for five-minute periods, a density determination being made after each ignition. The results were; 4·908, 4·908, 4·919, 4·921, 4·923, 4·912. The material was then heated an hour longer and the density redetermined, the results being 4·924 and 4·923. In these and the following determinations the ignition was accomplished in 30 gm. platinum crucibles over a fairly powerful blast lamp. The question whether different preparations of the oxides in the same proportions had the same specific gravity could only be answered by making a series of such determinations. Complete duplicate series of mixtures were not made on account of lack of material, but the results given in the table, which appears below, show what agreement was obtained in each case. The average difference in density between different preparations of oxides having the same composition was 1·1 per cent. This appears to be the greatest source of error in the determinations, and shows that the method of preparing the oxides must be fixed as definitely as possible.

The detailed method of preparing the mixed oxides in condition for specific gravity determination was as follows: About three grams of the oxides were fused in a platinum dish with six times their weight of acid potassium fluoride till the mass was just liquid. The fusion was dissolved in 200^{cc} of hot water in a platinum dish, adding a little hydrofluoric acid to obtain a clear solution. The solution was made alkaline with ammonia, and after allowing the precipitate to settle, filtered on a rubber funnel and washed well with water containing ammonia. The precipitate runs through the paper if pure water is used. The precipitate was redissolved in the platinum dish, using as little dilute hydrofluoric acid and water as possible and evaporated to dryness. Ten cubic centimeters of concentrated sulphuric acid were added in such a way that the residue was completely moistened. The liquid was evaporated over asbestos till all hydrofluoric acid was expelled, stirring if there seemed to be danger of spattering. The residue was cooled, 200^{cc} of water added, and the solution made alkaline with ammonia, filtered, and the precipitate washed with dilute ammonia. The precipitate was transferred while moist to a 30 gram platinum crucible and ignited over a blast lamp for an hour. The residue was ground to a fine powder with water and was then ready for the density determination previously described. This method of preparing the oxides may appear longer than necessary, but we adopted it only after preliminary work had made it appear essential. Acid potassium fluoride was used in decomposing the oxides instead of potassium bisulphate because the latter does not render the oxides completely soluble in hydrofluoric acid if they have previously been ignited. This fusion with acid fluoride does not involve any loss of either columbium or tantalum by volatilization. To prove this, 1·3576 gms. of mixed columbic and tantalic oxides were subjected to the process outlined above and 1·3603 gms. were obtained. If the mixed oxides have not been ignited and are completely soluble in hydrofluoric acid, this may be used to dissolve them instead of acid potassium fluoride. The first precipitate with ammonia from hydrofluoric acid solution can not be ignited and used for density determination, as it contains fluorine after being ignited. Washing the precipitate with dilute ammonia will not remove all the fluorides.

Results.

In preparing the mixtures for density determinations, we were fortunate in obtaining very pure tantalum and columbium oxides. Dr. W. E. Ford supplied a sample of columbic oxide which had been given him by Prof. E. F. Smith. It had been prepared from the chloride and was exceedingly pure. Dr. Ford also supplied some tantalum oxide from Dr. W. R. Whitney of Schenectady, who stated that the material was considerably over 99 per cent pure. Dr. T. B. Osborne furnished us with considerable amounts of potassium tantalum and potassium columbium double fluorides which we recrystallized and converted into the oxides. The densities were as follows:

Columbic oxide (Smith)	4·552
" " (Osborne)	4·564
Tantalic " (Whitney)	8·716
" " (Osborne)	8·683

In making the mixtures, it was assumed that Smith's and Whitney's oxides were pure and that Osborne's columbic oxide contained 0·61 per cent tantalic oxide and his tantalic oxide

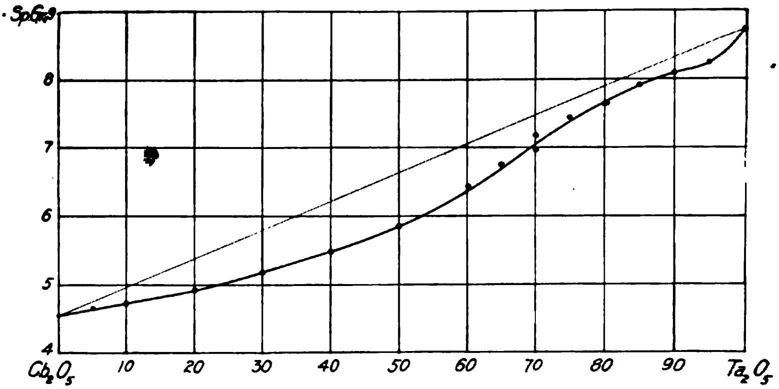
0·32 per cent columbic oxide. These values were calculated from the densities. The original intention was to make mixtures of the oxides at intervals of ten per cent. Irregularity in the curve showing change in density with change in composition when there was over 60 per cent of tantalic oxide caused us to repeat some of the determinations in this region, as we suspected an error in the work. We were led to the conclusion that in the mixtures containing a moderate excess (65–85 per cent) of tantalic oxide, the densities are not as constant as when other proportions are present. The table and curve given below will make this clearer. All the results which were obtained upon known mixtures are tabulated below with one exception. This result was obviously in error as the density was not approximately related to the composition. In most cases, the density of one mixture of any given composition was determined. Where the curve as plotted from the table showed irregularities, duplicate mixtures were made and the results enclosed in brackets in the table. All densities are referred to water at 20°.

Composition % Ta_2O_5	Specific gravity				Average specific gravity
0	4·555	4·549			4·552
5	4·652	4·647			4·650
10	4·744	4·748			4·746
20	4·929	4·929			4·929
30	5·203	5·197			5·200
40	5·474	5·474			5·474
50	5·852	5·847			5·850
60	6·437	6·431			6·434
65	6·719	6·763	6·730		6·737
70	7·189	7·170			7·083
70	6·958	6·992	7·008	6·981	
75	7·431	7·452			7·441
80	7·629	7·637			7·654
80	7·662	7·687			
85	7·885	7·925	7·963		7·961
85	8·01	7·99			
90	8·103	8·078	8·133		8·098
90	8·090	8·092			
95	8·245	8·241			8·243
100	8·725	8·684	8·730		8·716

The average of the results in the table are plotted in the figure.

The curve has some interest from the standpoint of solid solutions. The fact that the points as plotted do not lie on a straight line indicates that the oxides have formed a solid solution and not a mechanical mixture. The irregularities in the curve, which can hardly be due entirely to experimental error, suggest that the oxides are not soluble in each other in all proportions, but that tantalum oxide has taken up about 18 per cent of its weight of columbium oxide, and the latter over twice its weight of tantalum oxide. The intermediate mixtures would then consist of mechanical mixtures of each oxide saturated with the other. In these mixtures the variations in densities of different mixtures of the same composition are greatest. Points on this part of the curve should lie on a straight line if the interpretation of these results as suggested is correct.

Fig. 1.



Analyses of Minerals by Density Method.

The analysis of a sample of stibiotantalite from the Brush collection was carried out using the indirect method for determining the relative proportion of tantalum and columbium oxides. The density of the sample was 6·80 and the weight four grams. The method used was as follows: Two one gram samples and a two gram sample were each dissolved in about 20^{cc} of hydrofluoric acid. Some white insoluble material remaining undissolved was filtered off and its weight deducted from that of the sample taken. The resulting weight was taken as that of stibiotantalite used for analysis. The solution containing an excess of hydrofluoric acid was diluted to 300^{cc} and hydrogen sulphide passed in until all antimony and bismuth were precipitated as sulphides. The precipitate was filtered, washed with water, and treated several times with yellow ammonium sulphide. The insoluble residue of bismuth sulphide was dissolved in nitric acid, precipitated with ammonium carbonate, filtered, washed, ignited and weighed as Bi_2O_3. The solution of antimony sulphide in ammonium sulphide was precipitated with sulphuric acid, (in the case of the two gram sample one tenth of the solution was used,) filtered in a porcelain Gooch crucible and washed with water. The crucible was supported in a triangle on a sand bath and covered with a 300^{cc} flask whose bottom had been removed. A glass tube and thermometer were fitted into the neck of the flask through a rubber stopper. The air in the flask was displaced by a rapid stream of carbon dioxide entering through the neck of the flask and escaping through the sand at the bottom. The temperature was raised to 240° and maintained for two hours, while carbon dioxide was passed in. At the end of this time all free sulphur had been removed from the Sb_2S_3 precipitate, as was shown by the weight remaining constant after further treatment. The crucible was allowed to cool in the atmosphere of carbon dioxide, its weight taken, and Sb_2S_3 calculated into terms of Sb_2O_3.

The filtrate from the precipitation with hydrogen sulphide contained columbium and tantalum in solution in hydrofluoric acid. It was evaporated to dryness, moistened with concentrated sulphuric acid, and heated until all hydrofluoric acid was expelled. Water was added and the solution made alkaline with ammonia, filtered, the precipitate washed, ignited, and weighed. After heating over a blast lamp for an hour the density was determined. In experiments 2 and 3 the hydrofluoric acid solutions containing tantalum and columbium were united in order to obtain enough material for a reliable determination of density. The results of the analysis are as follows:

	1	2	3	Average
Sb_2O_3	40·98	40·98	40·91	40·95
Bi_2O_3	...	0·50	0·69	0·60
Ta_2O_5	41·53	42·30	42·30	41·92
Cb_2O_5	16·56	15·82	15·82	16·19
		99·60	99·72	99·66
Density of mixed oxides of Ta and Cb	7·191	7·282	7·282	7·236

$$\text{Ratio of } \frac{Sb_2O_3 + Bi_2O_3}{Ta_2O_5 + Cb_2O_5} = 0{\cdot}92$$

The density method was also applied to the partial analysis of a Branchville columbite and for comparison tantalum and columbium were separated and determined by the Marignac method. The specimen contained no titanium. The oxides obtained in the course of analysis were soluble in hydrofluoric acid, so that preliminary fusion with acid fluoride was unnecessary. The solution was precipitated with ammonia, filtered, redissolved in hydrofluoric acid and evaporated with sulphuric acid, etc., as previously described. The results of the duplicate analysis are given in the following table:

Per cent Ta_2O_5 + Cb_2O_5 in mineral	Density of mixed oxides	Per cent Ta_2O_5 in oxides by density method	Per cent Ta_2O_5 in oxides by Marignac method	Per cent oxides in mineral by density method		Per cent oxides in mineral by Marignac method	
				Ta_2O_5	Cb_2O_5	Ta_2O_5	Cb_2O_5
1. 78·77	4·957	21·0	18·74	16·54	62·23	14·43	63·68
2. 79·04	4·918	20·0	17·21	15·81	63·23	13·60	65·75

It will be seen that the results are approximately alike by the two methods, but we believe the results by the density method are more accurate and they are certainly much easier to obtain. The specific gravity of the columbic oxide from one Marignac separation was found to be 4·612 corresponding to 96 per cent of columbic oxide and 4 per cent tantalic oxide, showing that some tantalum went with the columbium. It is probable also that some columbium crystallized with the tantalum double fluoride but the amount of tantalic oxide was too small for a density determination.

The authors wish to express their thanks to Dr. W. E. Ford and Dr. T. B. Osborne for the tantalum and columbium oxides used in this investigation.

Sheffield Chemical Laboratory,
New Haven, Connecticut,
July, 1910.

Art. XLIV.—*Note on a Recent Method for Separating Tantalum and Columbium;* by H. W. Foote and R. W. Langley.

A new method of separating tantalum from columbium was proposed recently by Weiss and Landecker.* This method consists essentially in fusing the mixed oxides with sodium carbonate containing a little nitrate and treating with hot water. Some tantalum, as sodium tantalate, remains insoluble and is removed by filtering and treated separately. The tantalum remaining in solution is precipitated by carbon dioxide. The authors state that if the conditions are properly adjusted, all the tantalum is precipitated, leaving columbium in solution. On the other hand, Rose† and Ostwald‡ state that both are completely precipitated by carbon dioxide from a sodium carbonate solution.

We have tried a considerable number of experiments following the directions given by Weiss and Landecker as closely as possible but varying certain conditions not defined by the authors. We were unable to make any satisfactory separation by this method. On the contrary, in every case nearly all the columbium precipitated with the tantalum. The authors state that a separation depends upon adjusting the amounts of reagents used, the method of fusion, and the concentration of the solution within narrow limits. These conditions, in our experiments, were adjusted to conform as closely as possible with the slightly indefinite directions given by the authors. The quantities of reagents and the concentration of solutions were also varied somewhat to effect a separation if possible. The method—taken from Weiss and Landecker—was as follows. The amounts of reagents used will be given in the table. About 0·3 gm. of a known mixture of tantalic and columbic oxides was fused with sodium carbonate over a blast till effervescence ceased. Sodium nitrate was added and the fusion continued about ten seconds. The fusion was treated with hot water on the steam bath for two hours and the insoluble residue filtered and washed with 5 per cent sodium bicarbonate solution. The filtrate, containing columbium and tantalum, was cooled and carbon dioxide passed in until no further precipitate formed. In the meantime, the insoluble sodium tantalate was boiled with dilute sulphuric acid and hydrogen dioxide to dissolve it. We were never successful in getting complete solution at this point. Sulphurous acid was added and the solution kept warm for two hours to reprecipitate the dissolved tantalum. The precipitate was filtered, washed, ignited and weighed. The oxide precipitated with carbon dioxide, which should have been pure tantalic oxide, was filtered and the weight after ignition added to the weight of tantalic oxide already obtained.

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* Zeitschr. anorg. Chem., lxiv, 65, 1909.

† Handbuch analyt. Chem., 6th ed., ii, 339.

‡ Grundlinien anorg. Chem., ed. 1900, 726.

The filtrate from the carbon dioxide precipitation was acidified with sulphuric acid, an excess of sulphurous acid added, the solution boiled and allowed to stand. The precipitate which should have contained all the columbium was filtered, washed, ignited and weighed. As a precaution ammonia was added to the filtrate to be sure that no columbium was left in solution.

The results of these experiments are tabulated below. They show that we obtained no separation in any case, but that columbium was almost quantitatively precipitated with the tantalum by carbon dioxide. The precipitate must have carried some alkali with it as the amount of tantalum and columbium oxides recovered was always apparently greater than the amount used.

The results of the experiments are tabulated below.

No.	Ta_2O_5 taken (gms)	Cb_2O_5 taken (gms)	Ta_2O_5 found (gms)	Cb_2O_5 found (gms)	Na_2CO_3 used for fusion (gms)	$NaNO_3$ used for fusion (gms)	Volume when CO_2 was passed in (cc)	Remarks.
1.	·2100	·0900	·3025	none	about 2 gms.	about ·1 gm.	600	
2.	·2129	·0913	·3219	·0117	·58	·05	250	
3.	·1975	·0846	·2903	·0125	1·2	·05	250	A precipitate separated on standing over night before passing CO_2.
4.	·2465	·0616	·3167	·0030	·6	·05	250	Precipitate with CO_2 separated in 1 hour stopped CO_2 in 1½ hours.
5.	·2362	·0591	·2974	·0056	1·2	·05	250	
6.	·2580	·0645	·3193	·0167	1·8	·05	250	
7.	·2546	·0637	·3220	·0087	1·8	·05	250	Fused mass when treated with water contained many crystalline plates.
8.	·2728	·0682	·3425	·0037	1·8	0·1	250	
9.	·2838	·0710	·3654	trace	1·8	0·1	250	Precipitate with carbon dioxide became crystalline on boiling.

The results have convinced us that the method in its present form is unreliable but it is possible that other conditions can be found which will permit a separation. If this could be done the method would be exceedingly valuable.

Sheffield Chemical Laboratory, New Haven, Connecticut.

ART. XLV.—*On the Symmetric Arrangement in the Elements of the Paleozoic Platform of North America;*[*] by RUDOLF RUEDEMANN.

WE wish to present certain facts indicating that the structural development of eastern North America has taken place in such a fashion that a notable symmetric arrangement of its elements has resulted.

This arrangement becomes especially distinct when the large area of Paleozoic rocks extending from the Canadian protaxis southward is considered by itself. This area, which is roughly bounded on the west by a line connecting the head of Lake Superior with the Ozarks and on the east by a line inclosing the Adirondacks and Appalachia, we may for convenience term the *Paleozoic platform of North America.* It corresponds in its relation to the Canadian shield with that of the "Russian platform" of the European geologists to the Baltic shield. A glance at the geologic map of North America will show that this platform is a direct southward continuation of the Canadian shield or protaxis and bounded by southward converging lines that are direct continuations of the boundaries of that shield,[†] as described by Suess and Willis. In the west the platform, like the Canadian shield, is separated from the Rocky mountain area by the north-south transcontinental depression that extends from the Gulf of Mexico to the mouth of the Mackenzie river and is occupied by Cretaceous and Tertiary rocks.

In comparing the sketch map (fig. 1) with the diagram (fig. 2) in which separate shading brings out the elevated and depressed regions, it is seen that on either side of the Canadian shield or protaxis [A], there stand out, like cornerstones, two separate Precambrian areas, the Isle Wisconsin [D_2] and the Isle Adirondack [E_2] in quite symmetric positions. Each has its extension connecting it with the protaxis in symmetric position, that of the Isle Wisconsin being directed northeast (partly submerged by Lake Superior), that of the Isle Adirondack northwest. From each of these extensions there runs outward, along the margin of the shield, a deep depression, the Lake Superior basin [D_1] and the St. Lawrence basin [E_1]. The latter is less distinct through the disturbing influence of

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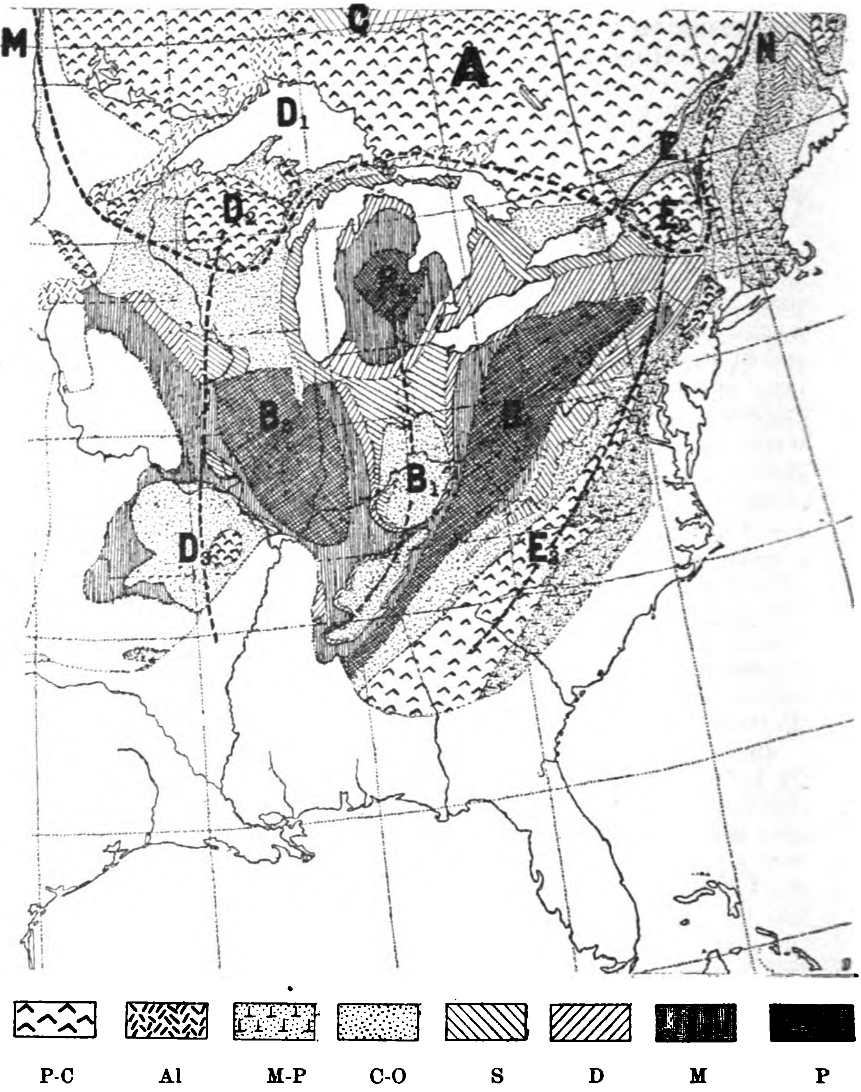
[*] Condensed from N. Y. State Museum Bulletin 140, pp. 141–149, 1910.

[†] The Mesozoic and Cenozoic embayment of the Mississippi Valley is, in this discussion, left out of consideration, because of younger age; likewise the belt of Carboniferous rocks to the west and southwest of the Ozarks, that forms the outer slope of the western arm of the platform, roughly corresponding to the area of metamorphic rocks on the opposite slope of the other arm, and properly belonging to the transcontinental depression.

FIG. 1.



P-C, Precambrian. Al, Algonkian. M-P, Metamorphosed Paleozoic. C-O, Cambro-Ordovician. S, Silurian. D, Devonian. M, Mississippian. P, Pennsylvanian.

FIG. 1. GEOLOGICAL SKETCH MAP OF THE EASTERN UNITED STATES.

MN, southern boundary of Canadian shield, A. D_2 and E_2, the symmetric Isles Wisconsin and Adirondack. D_1 and E_1, the adjoining marginal depressions of the shield. D_2-D_3, guide line of western arm of platform ; E_2-E_3, that of the eastern arm. D_3, Isle Ozark. E_3, Isle Appalachia. B_1-B_2, guide line of axis of eastern basin. B_1, Cincinnati geanticline. B_2, Michigan basin. B_3 and B_4, symmetric subbasins.

the Appalachian folding and probably much obscured by extensive overthrusting from the southeast along "Logan's line." The effect of Appalachian folding by crushing in one side of the symmetric structure here set forth, will be discussed more fully in another chapter (see p. 408).

From each of these cornerstones there extends southward, like an arm, a broad belt of Precambrian and early Paleozoic rocks, nearly the full length of the continent. The western arm can be traced by the great southward extension of the Precarboniferous rocks of Isle Wisconsin to near the neighborhood of Burlington, the Siluro-Devonian inlier along the Mississippi above its junction with the Missouri and the large Precambrian-Cambro-Silurian inlier or uplift of the Ozarks in Missouri and Arkansas* [D_2]. Its "Leitlinie" is shown in the thick broken line marked D_2 through D_3. The eastern arm [E_2–E_3] has been badly overridden, broken up and forced inward by the tangential pressure that has produced the Appalachian folds. It is, nevertheless, still easily recognized in the belt of Precambrian and Precarboniferous rocks, extending south and southwestward from New York as far as Alabama.

The two arms have later been somewhat disturbed and obscured, especially the western one, by the breaking down of certain portions south of Isle Wisconsin, where the Carboniferous has transgressed it, and the eastern one by the submergence of portions southeast of the Adirondacks and by extensive folding. In their original position the two arms may be conceived as approaching each other somewhat in the south, although not nearly so much as they do now, in consequence of the forcing inward of the eastern arm, for if the considerable shortening of the eastern basin indicated by the Appalachian folds is taken into account and the basin spread out to its original width, the eastern arm would probably take a position fully corresponding to that of the western.

These two arms bound a large basin, the "Paleozoic eastern basin," now occupied by the basin of Ohio and the Great Lakes. In the middle of this an elongated low elevation formed, now indicated by the Cincinnati and Nashville "uplift."

The axial position of this uplift (see line B_2-B_1, fig. 1) suggests that it may partake of the nature of the "geanticlinal median"† that according to Haug‡ forms along the median

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*** The Ouachita mountains in Arkansas probably represent, according to Dr. Ulrich's description [in Preliminary List of Papers, Geol. Soc. Am., 21 Meet. 1908, p. 21] and as already indicated by their strike, a different element and will, for this reason, be left out of the discussion for the present.**

† Dana clearly recognized this uplift as a geanticline.

‡ Haug, Émile, Bull. Soc. Géol. Fr. (3), xxviii, 617, 1900; and Traité de Géologie I, 164, 1907.

line of a geosyncline preparatory to more extensive folding. The southern portion of the uplift which, according to its normal position to the basin and the Precambrian arms, should extend due south, has been affected by the Appalachian folding and twisted into a southwest direction. As a result of the

Fig. 2.

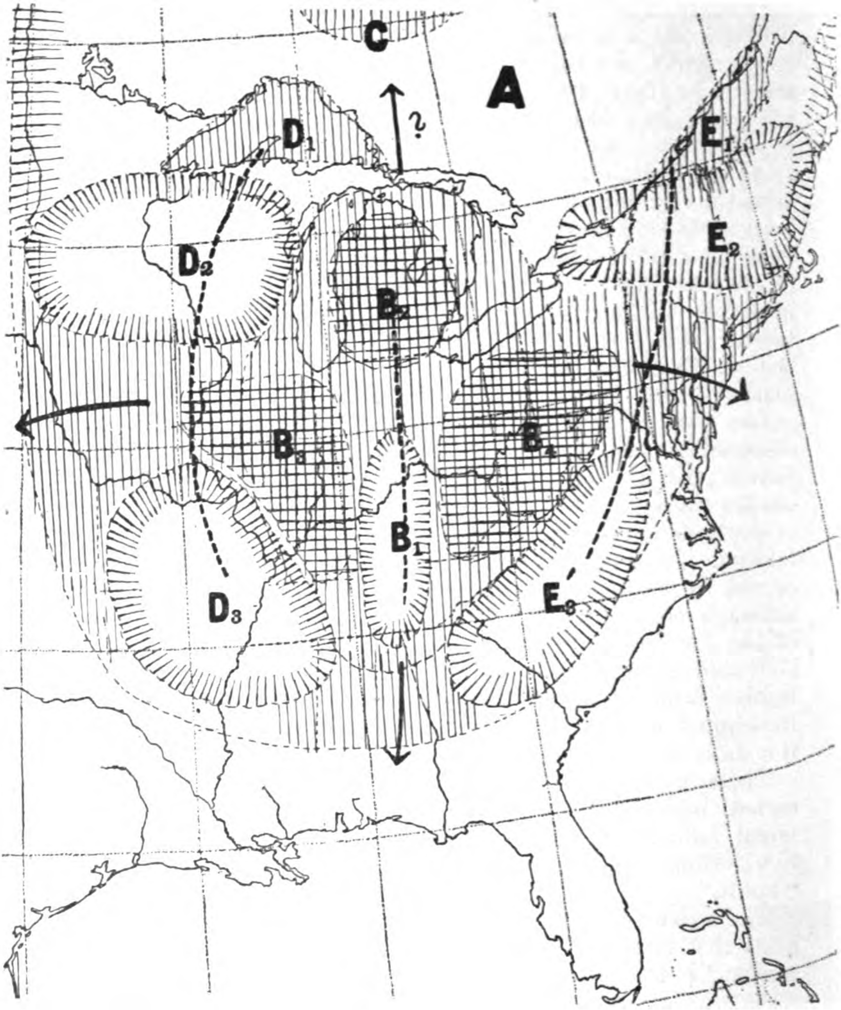

Fig. 2. Diagram to show events on southern slope of North America still without interference of Atlantic pressure. Lettering as on figure 1. Arrows indicate main outlets of basin B.

warping of the axis of the basin, two separate symmetric basins have been formed,* one, the Eastern Interior, and the other, the East Central basin. On account of the approach of the Precambrian arms in the south, these basins do not extend north and south, but extend symmetrically to northwest and northeast. The Ohio river from the Pennsylvania to the West Virginia line flows along the axis of the eastern basin.

The northern portion of the Paleozoic platform that lies to the north of the Cincinnati geanticline assumed the aspect of a separate subcircular basin, typically indicated by the Michigan coal field and the locations of Lake Michigan and Lake Huron. It also lies symmetric to the whole arrangement and with the Cincinnati uplift it is on the line of symmetry. It is possible that this Michigan basin, instead of being an independent depression, originated from the same warping force as the Cincinnati uplift, being the result of a longitudinal oscillation of the axis of the same geanticline, comparable to those more intensive longitudinal oscillations of the axes, which have been observed in some of the Alpine folds (see Haug, Traité, p. 211). The Canadian geologists, however, have claimed to find the influence of the Cincinnati uplift extending from the west end of Lake Erie farther north to Lake Huron. In this case it would seem that the Atlantic pressure had affected the entire extent of the uplift [see p. 408] giving it a direction subparallel to the Appalachian folds, and the Michigan basin would have to be considered as independent of the Cincinnati uplift, a view distinctly not supported by the general distribution of the formations around the basin.

The development of these symmetric structures may have taken place as shown in figures 1 and 2. In figure 1 the Canadian shield A and its Paleozoic platform are separated by the line M-N. First, then, an extensive depression affected the middle portion of the platform producing the Paleozoic eastern basin, fig. 2, B_2, B_4, and leaving two long embracing arms standing, the western one D_{1-3} and the eastern one E_{1-3}.

The following changes took place in the two arms and in the inclosed basin. The arms were broken up, with the result that on either side two principal isles, Isle Wisconsin [D_2] and Isle Ozark [D_3], Isle Adirondack [E_2] and Isle Appalachia [E_3] were formed. These isles are distinctly paired. On either side between the Canadian shield and the first isle a depression formed, the Lake Superior basin [D_1] and the St. Lawrence basin [E_1], and other depressions between the first and second isles.

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* Dana [Areas of Continental Progress in North America, etc. Bull. Geol. Soc. Am., i, 41, 1890], recognizing the importance of the regions of shallow seas represented by the Cincinnati uplift and the Precambrian region of Missouri as regards rock-making, has distinguished these basins by the terms here used.

In the Paleozoic eastern basin a broad low anticline, the Cincinnati-Nashville parma [B_1], arose*; exactly in the axial line of the depression and in continuation of this line of elevation the northern part of the basin sank down into an axial basin, the Michigan subbasin [B_2]. On either side of the parma, between the latter and the Precambrian arms, two basins, the East Central [B_3] and the Eastern Interior basin [B_4], were formed, in such an arrangement that they converge southward and are exactly symmetrical to the axial line of the eastern basin.

The stress from the sub-Atlantic pressure, the cause of the Appalachian folding and overthrusting crushed or crumbled this symmetric structure from the southeast, its influence being felt in the whole eastern portion of the area. Its effect is seen by a comparison of figures 1 and 2. Following Claypole's earlier estimates, Willis (Bull. Geol. Soc. Am., xviii, 404, 1907) remarks that "it is a moderate statement to say that during the Appalachian revolution that portion of the continent southeast of the Cumberland Plateau rim moved northwestward at least 50 miles."

On account of its oblique direction to the north-south axis of the Paleozoic eastern basin, the stress reaches deepest into the latter in the south, where it has clearly turned the Nashville portion of the Cincinnati-Nashville parma aside. It further lengthened the Eastern Interior basin, and extended it into southeastern New York, or considerably farther north than the opposite East Central basin. Moreover, it may have produced secondary depressions east of the Michigan basin, which have finally found expression in Lakes Erie and Ontario. The principal facts suggesting the latter view are the general parallelism of these lake basins with that portion of the Appalachian folds southeast of them† whence the push came. It should, however, in this connection be taken into account that it can have been but the last stages of Appalachian folding that produced the gentle down-warping of these basins, since the outwardly convex strike of the earlier Paleozoic formations (best seen at the west end of Lake Ontario) shows that this was an elevated region until at least Devonian time. It is, therefore, quite possible that these depressions are the counterparts of the late (early Tertiary) domelike warpings in western Pennsylvania* and southern New York, to which their longitudinal direction clearly corresponds.

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* Suess has termed such broad warpings "parmas."

† By drawing a straight line connecting the folds from the Tennessee-Virginia line to the Pennsylvania-New Jersey line, one obtains a line that indicates the general direction of this portion of the folds, and that line is parallel to the two lake basins.

The joining of the Appalachian folds that die out in southern New York by a new north-south system of folds in eastern New York, brings the folded region close against the Adirondack isle and produces another depressed "Vorland," the Champlain basin. The Ottawa-Montreal basin that corresponds in its position and also in its form, in surrounding the north side of the Adirondack isle, to the Lake Superior basin, has also been much encroached upon by the westward pressure of the folded region and no doubt to no little amount by extensive overthrust.

It will be seen that with the conception here presented of the geologic development of the eastern United States, the Great Lakes fall, by the first impetus to the formation of their basins—omitting the later accessory agencies, as glaciation and pre-glacial drainage-lines—into three groups, viz:

(*a*) Lake Superior, originating from the breaking down of one of the arms of the Canadian shield.†

(*b*) Lake Michigan and Lake Huron. Their location and form correspond to the Michigan basin, where they roughly follow the Devonian belts.

(*c*) Lake Erie and Lake Ontario, either depressions originating from the action of the Atlantic tangential pressure, or counterparts of later warpings in the upper Ohio basin and western New York.

We have thus far left out of consideration the Appalachian basin or "geosyncline" which occupies a narrow strip on the west side of Appalachia and is continued northward through New York and Vermont into Canada. It has later become the site of the Appalachian folds. Ulrich and Schuchert‡ have clearly shown that this basin became early subdivided by longitudinal and transverse barriers into a number of smaller basins. In their directions these barriers foreshadow the later, more intensive Appalachian folding, and are early indications of the influence of the pressure acting from the Atlantic basin upon and through Appalachia. It is certain that the Appalachian basin itself which became the site of the intense folding resulted from the Atlantic pressure upon Appalachia, due to suboceanic spread. It is therefore a foreign element, so to say, in the geologic history of the Paleozoic platform, which, however, has strongly obscured the original symmetry of the latter. While all changes here noted on the platform are of epeirogenic character, the Appalachian folds are an orogenic feature.

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* See Campbell, M. R., Bull. Geol. Soc. Am., xiv, 277, 1903.

† The Lake Superior basin clearly antedates all the others, at least with its western arm, which rests in Algonkian rocks that indicate a very early depression in the Canadian shield.

‡ N. Y. State Mus. Bull., lii, 633, 1901.

While in general the isles have emerged in Paleozoic times and the basins have been submerged, there have been continuous changes in the amount of emergence and submergence. This fact becomes especially manifest through Professor Schuchert's paleogeographic maps,* and it is probable that these subsidences and elevations took place in rhythmic pulsations.

With all these continuous changes, however, the sum total of the elevations of Isle Wisconsin, Isle Adirondack, Ozarkia and Appalachia has been greater than that of the depressions, and they represent, therefore, positive elements of the continent in the sense used by Willis,† while the depressions are negative elements in which, however, in some zones, as in the Cincinnati uplift, the algebraic sum of the unconformities and sediments may approach zero. The most conspicuous negative element is the Appalachian basin with its immense sedimentation.

The symmetry of arrangement of the platform is likewise but a surplus of symmetric features in the general structure over many asymmetric details in the different stages through which the platform has passed. This again is well shown by the charts of Professor Schuchert. It will be seen that at times the Nashville uplift was joined to Appalachia, and the Eastern Interior basin moved northward, while the East Central basin was divided by a secondary peninsula (Kankakee) and Ozarkia joined to a vast western tract. But at the same time the two arms of the platform with their northern isles Wisconsin and Adirondack (as peninsulas) and the southern land bodies of Ozarkia and Appalachia remained distinct elements, and likewise the Mediterranean-like basin remained defined in its general outline.

The main outlets from the Paleozoic sea (see fig. 2) passed eastward between Isle Adirondack and Appalachia and westward between Isle Wisconsin and the Ozark uplift and southward between Ozarkia and Appalachia. The Wisconsin and Adirondack isles have apparently been frequently attached to the protaxis. This becomes especially manifest in the case of the Adirondack isle, where the Beekmantown, Pamelia, Chazy, Lowville and probably also Black River formations do not cross the connecting Frontenac axis. The St. Lawrence depression, however, frequently became an important highway of migration (as in Beekmantown, Onondaga and Hamilton times) through its southward connection, by different straits, at different times with depressions between the Isle Adirondack and Appalachia (see *p. e.* Schuchert's map of Onondaga time).

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* Bull. Geol. Soc. Amer., xx, 427-606, 1910.

† Willis, Bailey, Bull. Geol. Soc. Amer., xviii, 389, 1907.

There are facts available that indicate approximately the time when the symmetric arrangement of the Paleozoic platform took place. As we have noted before, Algonkian sedimentation took place around Lake Superior (see fig. 1), but aside from this somewhat independent depression, the whole platform was, according to Walcott's investigation,* above sea level until Upper Cambrian time, with the exception of the Appalachian geosyncline. The relation of the Upper Cambrian deposits to the Isles Wisconsin and Adirondack would indicate that in this period the separation of the Paleozoic eastern basin and of the inclosing arms took place and probably also the beginning of the breaking up of the arms. The Isles Wisconsin and Adirondack, Ozarkia and Appalachia have remained above the sea since the end of the Lower Silurian. In Upper Silurian time the Cincinnati parma had become a prominent feature, although the Cincinnati and Nashville parts of the same were again separated repeatedly, as in Hamilton and Mississippian times, by the submergence of the middle part. In Carboniferous (Mississippian and Pennsylvanian) times all the subdivisions of the platform distinguished above were fully developed. Since then the platform has remained land, with the exception of the Mesozoic Mississippi embayment.

Summary.

The writer endeavors to point out:

1. That the Paleozoic platform of North America extending south from the Canadian shield forms, together with the latter, a structural element of the continent, that is similar in outline to the latter.

2. That the Paleozoic platform exhibits a symmetric arrangement of its parts. This symmetric arrangement consists in the presence of a median basin (Paleozoic eastern basin) that is flanked on both sides by broad elevations, extending southward from the Isles Wisconsin and Adirondack which possess symmetric positions with reference to the Canadian shield. Ozarkia and Appalachia, the two remaining portions of elevations, hold like symmetric positions.

3. The axial line of the Paleozoic eastern basin is occupied by the Cincinnati-Nashville parma and the Michigan subbasin. The former divides the Paleozoic eastern basin into two similar and symmetric basins, the Eastern Interior and East Central basins.

4. The disturbing factor has been the Atlantic pressure, which pushed the eastern arm in and produced the Appalachian basin folds, its effect reaching as far as the Nashville uplift.

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* See Walcott, U. S. Geol. Survey Bull., lxxxi, pl. 2, 3, 1891.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Behavior of Metallic Copper towards Gases*—**SIEVERTS** and **KRUMBHAAR** have made an elaborate study of the solubility of several common gases in solid and liquid metallic copper. The behavior of oxygen is well known; it dissolves in molten copper in the form of cuprous oxide, and upon solidification it is not given off, even in an atmosphere free from oxygen. Nitrogen, carbon dioxide and carbon monoxide are not absorbed either by the solid or molten metal. Hydrogen is absorbed by solid copper at elevated temperatures. The diffusion of this gas through a thin copper tube was observed at 650° C. and it was found that the rapidity of diffusion and the solubility increases with the temperature. Above the melting point of copper the solubility of hydrogen in the metal becomes greater, and it increases again with the temperature, at least as far as 1500° C., the temperature to which the measurements were carried. At constant temperature the solubility of hydrogen in the molten copper varies according to the square root of the pressure. Solid copper absorbs no sulphur dioxide, but the liquid metal dissolves it abundantly. This solubility, at constant pressure, increases with the temperature from the melting point to 1500° C., becoming more than twice as great at the latter temperature. The solubility of sulphur dioxide, like that of hydrogen, in molten copper, varies according to the square root of the pressure. The agreement of hydrogen and sulphur dioxide in regard to their pressure solubility appears to contradict a theory advanced by van't Hoff to the effect that this peculiar pressure relation is due to a change from the molecular (H_2) to the atomic form upon solution, for the SO_2, with three atoms in it, should not show the same relation. The increase in solubility of these gases with the temperature shows that their dissolving must take place with the absorption of heat, and this behavior seems to be general with solutions of gases in metals, although it has been observed very rarely in the solutions of gases in water.—*Zeitschr. physikal. Chem.*, lxxiv, 277. H. L. W.

2. *The Diffusion of Crude Petroleum through Fuller's Earth.*—The fact that natural oils have been changed in composition by percolation through porous strata in the earth is now well recognized, since various experiments have shown that such fractionation may be carried out by artificial means. **GILPIN** and **BRANSKY** have recently described an extensive series of experiments with natural products and mixtures, using tubes packed with fuller's earth, and have confirmed this view of an important cause of the variations in composition of natural oils. They reach

the following conclusions in regard to diffusion upward through fuller's earth: 1. With a solution of benzine and paraffin oil, the benzine tends to collect in the lower part, and the paraffin oil in the upper part. 2. When crude petroleum is used, the oil that is displaced by water from the earth of the upper part has a lower specific gravity than that obtained in the same way from the lower part. 3. As the fractionation proceeds the range of specific gravity in succeeding fractions becomes smaller, indicating a tendency towards the production of mixtures which will diffuse without change. 4. In the fractionation of petroleum the lighter portions toward the top become gradually freer from unsaturated hydrocarbons and sulphur compounds. 5. Fuller's earth tends to retain the unsaturated hydrocarbons and the sulphur compounds, thus exercising a selective action upon the oil.—*Amer. Chem. Jour.*, xliv, 251. H. L. W.

3. *Vacuum-tight Seals between Iron and Glass.*—It has been found by H. J. S. SAND that an iron wire sealed into glass may be made vacuum-tight by passing over the protruding wire, while the glass is still hot, a small piece of heated steel tubing and pushing this into the soft glass for a distance of a few millimeters. After cooling, the outer end of the tube is soldered to the wire. The explanation is given that the tube by its contraction compresses the glass within it and thus forms an effective seal. Tubes into which iron wires 1^{mm} diameter have been sealed in this manner have been exhausted to a cathode-ray vacuum and have maintained this for four months, up to the time of publication. It is not yet certain that the seals will have a practical importance in replacing platinum in the case of rapid wholesale manufacture. The author points out that, as far as he is aware, previous proposals to replace platinum for this purpose by iron-nickel alloys or thin, flat strips of copper have met with little success. It is to be hoped that the method under consideration or some other satisfactory process will soon be devised for the saving of platinum.—*Chem. News*, cii, 166. H. L. W.

4. *The Structure of Meteoric Alloys.*—W. GUERTLER has discussed the structure of the iron-nickel meteorites from the point of view of modern metallography. Fränkel and Tiemann have previously reached the conclusion that the meteoric structure is metastable, since upon heating to 800° C. the material then behaves like artificial alloys, and shows no evidence of again attaining the well-known meteoric structure. Guertler's conclusion, which appears to be well sustained by his arguments, is, in short, that the meteoric structure is a stable one requiring an exceedingly long time for its formation. He believes that the temperature at which the change takes place is comparatively low and consequently very slow, and that there is no need to assume a metastable condition in the natural alloy.—*Zeitschr. physikal. Chem.*, lxxiv, 428. H. L. W.

5. *Liquefaction of Helium.*—H. KAMERLINGH ONNES describes his method of liquefying helium and states its properties. The

point of ebullition of liquid helium is 4·3 absolute degrees. When this value is corrected for proper transference of helium to the absolute scale, the point of ebullition will probably be 4·5. The pressure at the triple point is less than 1^{cm} of mercury. According to corresponding states, the temperature corresponding to the pressure of 1^{cm} is in the neighborhood of 3 absolute degrees and, nevertheless, the liquid is still perfectly mobile. Liquid helium has a very low density, 0·15, which leads to a provisional value of b of 0·0007. This gives for the critical pressure an approximate value of 2 or 3 atmospheres. At the point of normal ebullition the ratio of the density of the vapor to that of the liquid is in the neighborhood of $\frac{1}{11}$. This indicates a critical temperature hardly higher than 5 absolute degrees, and a critical pressure a little greater than 2·3 atmospheres. The provisional value of the coefficient of pressure a is 0·00005, the smallest value of a relative to different bodies, and lower than that of hydrogen, which for a long time was considered 0.—*Communications from the Physical Laboratory of Leyden*, No. 108. J. T.

6. *Photoelectric Fatigue.*—Dr. H. STANLEY ALLEN reviews the theories in regard to this fatigue and thus summarizes them :—

(1) A chemical change, such as oxidation of the surface.

(2) A physical change of the metal itself, as, for example, roughening of the surface.

(3) An electrical change in the formation of an electrical double layer (Lenard).

(4) A disintegration of the metal due to the expulsion of electrons by light (Ramsay and Spencer).

(5) A change in the surface film of gas or in the gas occluded in the metal (Hallwacks).

Dr. Allen concludes from his own experiments that we must look to the gaseous films on the surface of the metals for the explanation of the chief effects of photoelectric fatigue.—*Phil. Mag.*, Oct. 1910, 564–573. J. T.

7. *A New Radiant Emission from the Spark.*—Professor R. W. WOOD shields the light of a spark from the eye by placing the spark behind a vertical strip of metal. No illumination is seen by the eye, but a photographic plate shows an actinic effect in the air surrounding the spark. The emission is absorbed by oxygen, and may be analogous to "Entladungsstrahlen."—*Phil. Mag.*, Oct. 1910, 707–712. J. T.

8. *Sterilization by Ultra- Violet Rays.*—At first sight it would seem that ultra-violet rays would be absorbed to so great an extent by liquids that bacilli could not be reached at any depth. A millimeter thickness of water absorbs completely waves below 1800. M. BILLON DAGUERRE, however, has discovered that the ultra-violet rays exert remarkable sterilizing effect on water. It seems possible that it may be a surface effect which is transmitted from bacilli to bacilli, for the light certainly has little penetrating power. The sterilizing action appears to be confined to clear water; impurities, suspended particles and colloids arrest

it. M. Billon Daguerre places a mercury vapor lamp in a tube through which the water circulates.—*La Revue Electrique*, May 15. J. T.

9. *International Congress of Radiology and Electricity.*—The second International Congress of Radiology and Electricity was held at Brussels, September 13–15 inclusive, 1910, the first congress having been held at Liège in 1905. The attendance reached nearly five hundred, and a very considerable proportion of the active workers in radio-activity and electronics were present at the various meetings. The formal ceremonies opened with a reception at the Bourse on the evening of the 12th, and the work of the Congress began on the following morning at a meeting held in one of the buildings on the grounds of the Exposition, where the presidential address was delivered by Professor de Heen, and various matters connected with the organization of the congress were arranged. On the afternoon of that day the members reassembled at the University and engaged in an interesting discussion in regard to standards and nomenclature. Attention was called by Professor Rutherford to the present importance of adopting a uniform standard for radio-active substances, and he pointed out that during the past year the standard specimens of radium salts employed in the leading laboratories of different countries had been compared under his direction and had been found to exhibit a marked lack of agreement. He was, therefore, convinced that for the successful development of the quantitative study of radio-active magnitudes the adoption of a uniform radium standard which could be accepted by all was highly desirable. Mme. Curie also spoke approvingly in regard to this proposal, which was heartily supported by all present at the meeting, and it was finally voted that a committee, the members to be appointed by Professor Rutherford and Mme. Curie, should be formed, and that this committee should consider the special needs and determine the conditions under which a suitable standard should be prepared and preserved. The matter of nomenclature was also briefly considered and it was generally agreed that at present there was nothing to be gained by the adoption of a more systematic nomenclature, as has been suggested by some, the present system being quite as satisfactory in all respects as any other which had been as yet proposed. The meeting then listened to an account by Mme. Curie of her recent interesting experiments of isolation of metallic radium. A number of other papers were also presented. On the following days the congress met in different sections for the reading of papers, of which a large number were presented on different subjects relating to radiology and electricity. These will be published later in the transactions of the Congress. Among the many pleasant features of the meeting were the reception at the town hall by the Municipality, and the admirable performance to which members were invited at the Théâtre Royal de la Monnaie. At the last meeting a committee, with members from different countries, was

appointed to have charge of the next congress, which there is reason for believing may be held within the next year or two. The committee appointed to have charge of the standards consisted of Mme. Curie and M. Debierne for France, Professors Rutherford and Soddy for Great Britain, Professor Geitel and Dr. Hahn for Germany, Professors St. Meyer and von Schweidler for Austria, Professor Boltwood for the United States and Professor Eve for Canada.

The Standards committee reported at the last meeting of the Congress, and its recommendations were adopted. They were substantially as follows:

1. Mme. Curie has kindly agreed for the purposes of the standard to prepare a quantity of the purest obtainable anhydrous radium chloride containing about 20 milligrams of radium (element).

2. When the committee have reimbursed Mme. Curie for the cost of the Radium Standard, this will come under the control of the committee and will be used only for the measurement and comparison of secondary standards by means of the γ-rays. The original standard is to be suitably preserved and deposited in Paris.

3. Through the committee, and at their discretion, national scientific laboratories and bureaus of standards willing to pay the costs are to be provided with certified secondary standards.

4. By such methods as, after due consideration, meet with the approval of the committee, smaller subsidiary standards are to be prepared for distribution.

5. As radium emanation is now so generally used in scientific investigations, the committee consider the adoption of a unit for the measurement of the amounts of radium emanation desirable. The committee recommend that the name "Curie" be given to the quantity or mass of emanation in equilibrium with one gram of radium (element). The milli-curie would thus be the amount of emanation in equilibrium with one milligram of radium.

6. The question of proposing special names for units of measurement of minute quantities of radium and its emanation is under consideration, but no definite conclusions have as yet been reached.

7. As some members of the committee are not present at the Brussels Congress, and as it has not been possible to obtain imformation as to their views on these questions, the recommendations here made are not necessarily final. The committee reserves the power to modify them if on further consideration this appears to be desirable.

The preparation of a standard of pure radium salt is now assured. The advantages of having such a standard with which material used for various scientific investigations in different parts of the world can be compared is apparent, and it will also be extremely useful to have a definite standard, on the basis of which quantities of radium salts to be sold or purchased can be measured. In the past great difficulties have been encountered in conducting commercial transactions involving radium salts, as, lacking any definite and accepted standard of quality, some dealers have been in the habit of selling as pure radium salts material of distinctly inferior quality. As the value of radium salts sold in the United States up to the present is probably considerably in excess of five hundred thousand dollars, the importance of having a definite and reliable check on the purity and strength of these preparations is most essential. The plan of the committee, known as the International Radium Standards committee, is to obtain the funds to cover the cost of the primary standard either through the governments or the scientific societies of the countries represented on the committee, or possibly through the coöperation of the International Bureau of Standards at Paris, where it is planned to ultimately deposit the Primary Standard. The committee sincerely desire the coöperation and assistance of all interested in the matter of the preparation of the present standard and communications in regard to this matter should be addressed to the Secretary of the Committee, Prof. Stefan Meyer, Institut fur Radiumforschung, Waisenhausgasse 3, Vienna IX, Austria.

B. B. BOLTWOOD.

II. GEOLOGY AND NATURAL HISTORY.

1. *Publications of the United States Geological Survey;* GEORGE OTIS SMITH, Director.—Recent publications of the U. S. Geological Survey are noted in the following list (continued from vol. xxix, p. 363):

FOLIO, No. 171. Engineer Mountain Folio: Colorado; by WHITMAN CROSS and ALLEN D. HOLE. Pp. 13, with 3 colored maps and 15 figures.

BULLETINS.—No. 381. Contributions to Economic Geology, 1908. Part II—Mineral Fuels. MARIUS R. CAMPBELL, geologist in charge. Pp. 559, with 24 plates and 15 figures.

No. 419. Analyses of Rocks and Minerals from the Laboratory of the United States Geological Survey, 1880–1908; tabulated by F. W. Clarke, chief chemist. Pp. 323.

No. 425. The Explosibility of Coal Dust, by GEORGE S. RICE, with chapters by J. C. W. FRAZER, AXEL LARSEN, FRANK HAAS, and CARL SCHOLZ. Pp. 186, with 14 plates and 28 figures.

No. 426. Granites of the Southeastern Atlantic States, by THOMAS LEONARD WATSON. Pp. 282, with 27 plates and 20 figures.

No. 427. Manganese Deposits of the United States, with Sections on Foreign Deposits, Chemistry, and Uses; by EDMUND CECIL HARDER. Pp. 298, with 2 plates and 33 figures.

No. 429. Oil and Gas in Louisiana, wlth a brief Summary of their Occurrence in adjacent States; by G. D. HARRIS. Pp. 192, with 22 plates and 21 figures.

No. 430. Contributions to Economic Geology (Short Papers and Preliminary Reports), 1909. Several advance chapters have been issued, viz., A, on Gold and Silver; C, Lead and Zinc; D, Rare Metals; F. Structural Materials; G, Mineral Paints; H, Phosphate; J, Miscellaneous Nonmetallic Products; I, Salines.

No. 432. Some Ore Deposits in Maine and the Milan Mine, New Hampshire; by WILLIAM H. EMMONS. Pp. 62, with 3 plates and 23 figures.

No. 434. Results of Spirit Leveling in Delaware, District of Columbia, Maryland, and Virginia, 1896 to 1909, inclusive. R. B. MARSHALL, chief geographer. Work done in coöperation with the State of Maryland during the entire period, and with the State of Virginia in part of 1908. Pp. 74.

No. 435. A Reconnaissance of Parts of New Mexico and Northern Arizona; by N. H. DARTON. Pp. 88, with 17 plates and 8 figures.

No. 437. Results of Spirit Leveling in Maine, New Hampshire, and Vermont, 1896 to 1909, inclusive. R. B. MARSHALL, chief geographer. Work done in coöperation with the State of Maine, during 1899, inclusive. Pp. 59.

No. 442-A. The Mining Industry in 1909, and Alaska Coal and its Utilization; by ALFRED H. BROOKS. Advance chapter, pp. 1-84.

No. 444. Bibliography of North American Geology for 1909, with Subject Index; by JOHN M. NICKLES. Pp. 174.

WATER SUPPLY PAPERS.—No. 237. The quality of the Surface Waters of California; by WALTON VAN WINKLE and FREDERICK M. EATON. Pp. 142 with one plate.

No. 240. Geology and Water Resources of the San Luis Valley, Colorado; by C. E. SIEBENTHAL. Pp. 128, with 13 plates and 15 figures.

Nos. 246, 247, 249, 250, 251. Surface Water Supply of the United States 1907-8. Prepared under the Direction of M. O. LEIGHTON.—No. 246. Part VI. Missouri River Basin; by ROBERT FOLLANSBEE and J. E. STEWART. Pp. 311, with 13 plates and 2 figures.—No. 247. Part VII. Lower Mississippi Basin; by W. B. FREEMAN, W. A. LAMB, and R. H. BOLSTER. Pp. 124, with 2 plates and 2 figures.—No. 249. Part IX. Colorado River Basin; by W. B. FREEMAN and R. H. BOLSTER. Pp. 206, with 10 plates.—No. 250. Part X. The Great Basin; by E. C. LA RUE and F. F. HENSHAW. Pp. 151, with 7 plates and one figure. —No. 251. Part XI. California; by W. B. CLAPP and W. F. MARTIN. Pp. 363, with 7 plates and one figure.

NO. 253. Water Power of the Cascade Range. Part I. Southern Washington; by JOHN C. STEVENS. Prepared in coöperation with the State of Washington. Pp. 94, with 21 plates and 3 figures.

No. 255. Underground Waters for Farm Use; by MYRON L. FULLER. Pp. 58, with 17 plates and 27 figures.

No. 260. Preliminary Report of the Ground Water of Estancia Valley, New Mexico; by OSCAR E. MEINZER. Pp. 33.

2. *Federal Bureau of Mines;* Joseph A. Holmes, Director. Bulletin I. The Volatile Matter of Coal; by Horace C. Porter and F. K. Ovitz. Pp. 56, with 20 tables and 9 figures.—This is the first independent publication of the newly established Federal Bureau of Mines (see v. xxx, p. 292). The work here detailed is now centered in the experiment station at Pittsburg, Penn., and had its beginning in investigations carried on at the coal-testing plant erected at St. Louis in 1904 in connection with the Louisiana Purchase Exposition. The authors state that "The investigaion has already shown that the volatile content of different coals differs greatly in character. The volatile matter of the younger coals found in the West includes a large proportion of carbon dioxide, carbon monoxide, and water, and a correspondingly small proportion of hydrocarbons and tarry vapors. The older bituminous coals of the Appalachian region yield volatile matter containing large amounts of tarry vapors and hydrocarbons, difficult to burn completely without considerable excess of air and a high temperature. Coal of the western type, moreover, gives up its volatile matter more easily at moderate and low temperatures than that of the other type. The volatile matter produced at medium and low temperatures is rich in higher hydrocarbons of the methane type, such as ethane and propane, which contain a larger portion of carbon than is present in methane." The results are shown to have important economic applications of interest to engineers and mechanics in a variety of fields. Copies of the bulletin may be obtained by applying to the Director of the Bureau of Mines at Washington.

3. *Cambrian Geology and Paleontology No. 6—Olenellus and other Genera of the Mesonacidæ;* by Charles D. Walcott (Smithsonian Miscel. Coll.), 53, 1910, pp. 231–422, pls. 23–44.—Our knowledge of the large and diagnostic Lower Cambrian trilobites is here greatly extended and made easily comprehensible through an abundance of most excellent illustrations. Of these trilobites there are in America and Europe 33 (16 new) species distributed in the following genera: *Nevadia* new (1), *Mesonacis* (2 European, 1 American), *Elliptocephala* (1), *Callavia* (5 European, 2 American), *Holmia* (2 European, 1? American), *Wanneria* new (3), *Pædeumias* new (1), *Olenellus* (3 European, 9 American), *Peachella* new (1), *Olenelloides* (1 European). All of the genera (with one exception) common to America and Europe are of the Atlantic realm. The exception is *Holmia rowei* of the Cordilleran region, but it will very likely be shown to belong to another genus related to *Holmia*.

The stem genus and the oldest of the family is *Nevadia*, giving rise in one line to *Callavia*, *Holmia*, *Wanneria*, and in the Middle Cambrian to *Paradoxides*. Another evoluted into the remaining genera mentioned above, a branch that is not only the most specialized but also has the most characteristic genera of the family and of the Lower Cambrian. The evolution of this stock as worked out by Walcott demonstrates that the telson of

Olenellus is not homologous with the pygidium of most trilobites but that it is a specialized post-thoracic one at least 11 segments anterior to the pygidium in the most primitive genus of the family, namely *Nevadia*. In other words, when the specialized *Olenellus* is compared with the more primitive *Nevadia* it is seen that the former has not only lost its pygidium but at least 13 other post-thoracic segments, and that the telson of *Olenellus* is probably homologous with either one of the 15th to 17th post-cephalic segments of *Nevadia*, back of which in this genus there are still 11 other segments and the true pygidium. How these post-thoracic segments are lost and how the telson is developed out of a spine in the different genera is fully described and illustrated by the author. This unmistakable evolution probably also indicates that the telson of *Limulus* is not homologous with the pygidium of trilobites, but that it is as well a specialized thoracic segment, and one equivalent to a thoracic segment considerably in advance of the pygidium of its trilobite ancestors.

It is now also made more apparent that the head of the Mesonacidæ is highly specialized in that the compound eyes have traveled from the ventral to the dorsal side in the earliest ontogenetic stages, for they have the relative position of maturity so early as in the paraprotaspis stage. Further, the free cheeks are firmly united with the glabella, do not separate along the facial suture as in most trilobites, and in this again recall the similar condition in *Limulus*. Genera like *Olenellus* are, therefore, highly specialized trilobites and are decidedly removed from the primitive types of which *Atops* and *Conocoryphe* are examples.

For the first time the eye cavities in the Mesonacidæ have been discovered and are here illustrated. They are very much like those in *Limulus*.

As is well known, the author is assembling Cambrian fossils from all parts of the world and in the work here reviewed we get a glimpse of the grandeur of the Smithsonian collections. When his studies are completed we will not only have a detailed knowledge of the oldest fossil faunas of the world but as well a firm base upon which to build our phylogenies of the trilobites, phyllopods and brachiopods. C. S.

4. *Die Bellerophonkalke von Oberkrain und ihre Brachiopodenfauna;* by F. Kossmat and C. Diener, Jahrb. k. k. geolog. Reichs., 1910, pp. 277–310, pls. 14–15.—The Bellerophon limestone and dolomite of the eastern Alpine region are at the top of the Paleozoic section and in close connection with the Triassic. They are underlain by red and white sandstone and conglomerate that in turn rest upon the black slates of the Carboniferous. These littoral deposits evidently represent a new sea invasion and are correlated by Kossmat with the Grödener and Verrucano, the normal aspect of the southern Alpine Permian sandstone. Above the Bellerophon horizon there repose disconformably the sandy-micaceous Werfener beds of the Triassic characterized by *Pseudomonotis aurita*, *P. ovata* and *P. venetiana*.

This Permian limestone is often abundantly fossiliferous, but the diagenetic changes of these strata appear to have destroyed much of its life. On weathering the limestone is seen to be almost made up of Diplopora (calcareous algæ), what appear to be Stenopora (bryozoa), and foraminifera, but the Fusulinidæ are wholly absent. There are many other larger fossils, but these are rarely to be obtained in identifiable condition. Of these the most abundant species is *Productus* cf. *indicus*.

Diener identifies among others eight species of productoids, *Richthofenia* aff., *lawrenciana*, *Comelicania haueri* (the guide brachiopod of the Bellerophon limestone), *Hemiptychina* cf. *inflata*, and *Notothyris mediterranea*. The aspect of this fauna is, therefore, decidedly that of the Productus limestone of India and belongs in the Tethys faunal realm.

It is stated by Diener that the most abundant fossils are forms of Productus near *P. striatus*, *P. semireticulatus*, and *P. inflatus*, types that remind one very much more of the Pennsylvanian than the Permian. These are, however, the unprogressive forms and have not the stratigraphic value of the new brachiopod developments, such as Richthofenia, Hemiptychina and Notothyris. It is this contradictory associated evidence that has led Tschernyschew to regard the Productus limestone of India (which is of Permian age) as equivalent to the Upper Carboniferous of Russia, and which the reviewer opposed in this Journal for July and August, 1906.

Diener states definitely that the Bellerophon limestone and the Productus limestone are younger than the Upper Carboniferous. He adds: "The fauna of Schönbrunn and Schaschar (Upper Krain) teaches us that the anthracolitic brachiopods cannot be used [interprovincially] for detailed stratigraphic differentiation, even when the species are based upon trivial characteristics, although they may be so used in circumscribed areas as guide fossils in identical kinds of strata" (307). Further, that the Bellerophon limestone cannot be regarded as a transitional fauna to the Triassic. It is still rich in Paleozoic brachiopods, the corals and nautilioids are decidedly Paleozoic, while the few ammonites are of types occurring in the Permian and Lower Triassic of India. The bivalves are those of the Zechstein. The gastropods are somewhat more progressive in that the Triassic genera Marmolatella, Platychilina, Hologyra, and Trachyspira appear here for the first time, but in general the class is still Paleozoic. Therefore, the Bellerophon limestone is still Permian and has its clearest analogue in the Productus limestone of India.

Diener recommends that Waagen's term "Anthracolithic Epoch" be used for the combined Upper Carboniferous and Permian faunas because of the difficulties often locally encountered in separating these biota. Permo-Carbon cannot be so used as it is now applied to the Artinskian series. C. S.

5. *The Phylogeny of the Felidæ;* by William D. Matthew. Bull. Amer. Mus. Nat. Hist., vol. xxviii, pp. 289–316 and 15

text-figures.—In this brief paper Dr. Matthew has added one more to his series of excellent and lucid phylogenies. He divides the Felidæ into two phyla, the earliest known examples of which are Oligocene, as no Eocene carnivora are known from which the Oligocene sabre-tooths can be derived.

The distinctions of the phyla are clearly indicated in limb, vertebræ, ribs, but especially in the skull and dentition, the phylum leading to the modern genus *Felis* having sub-equal canines above and below and powerful biting jaws by means of which the neck of the prey can be crunched. The other phylum culminates in the huge sabre-tooth *Smilodon*, with relatively feeble lower canines but with immense, curved, dagger-like upper teeth used for ripping open the neck of the huge contemporaneous pachyderms the vertebræ of which could not be crushed by the jaws.

The abundance of sabre-tooth types in early times is correlated with that of the pachyderms, including the elephants, rhinoceroses, etc., while with their replacement by a swifter, thin-skinned, ungulate fauna the sabre-tooths gave way to the better adapted felines. Dr. Matthew denies the contention that over-specialization of the canine due to "momentum of evolution" was the final cause of the extinction of this interesting race, though *Smilodon* has often been used as evidence of the truth of this somewhat doubtful factor of descent. R. S. L.

6. *An Account of the Beaked Whales of the family Ziphiidæ in the collection of the United States National Museum, with remarks on some specimens in other American Museums;* by FREDERICK W. TRUE, Smithsonian Institution, U. S. National Museum Bulletin 73, pp. 1–89 and 42 plates.—The beaked whales which form the subject of this memoir are among the rarest of cetaceans with the exception of the bottle-nosed members of the genus *Hyperoödon*, the three genera *Mesoplodon*, *Ziphius* and *Berardius* being represented by about 100 known individuals more than half of which belong to the first-named genus. *Berardius*, the rarest, is known from about fourteen specimens altogether. Doctor True records but nineteen specimens of all the genera put together upon the east and west coasts of the United States. These specimens are represented by skeletons or skulls sometimes supplemented by photographs and casts and upon such material the main body of the work is based. On pages 76–77 is a list of the genera and species of existing ziphoid whales with their habitats. The illustrations are excellently reproduced half-tones, while the text gives a very clear and adequate knowledge of these strange cetaceans. R. S. L.

7. *Report on the Resurvey of the Maryland-Pennsylvania Boundary part of the Mason and Dixon Line by the Mason and Dixon Line Resurvey Commission*, O. H. TITTMANN, WM. BULLOCK CLARK, ISAAC B. BROWN. Pp. 412, with 72 plates and 8 figures, 1908. Published by the Maryland Geological Survey as Vol. VII, WILLIAM BULLOCK CLARK, State Geologist, Baltimore, 1908 (Johns Hopkins Press).—This resurvey was carried

out by the United States Coast and Geodetic Survey at the request of the states of Maryland and Pennsylvania. The purpose was to accurately reëstablish and mark the old line. The results show the high accuracy for the period of the work of the original survey from 1763 to 1768. A history by E. B. MATTHEWS of the various surveys of this line is also included. J. B.

8. *Maryland Geological Survey*, volume viii, 1908, WILLIAM BULLOCK CLARK, State Geologist. Pp. 486, with 26 plates and 27 figures. Baltimore, 1909 (The Johns Hopkins Press).—This volume contains an assemblage of papers. The first part deals with the highways, by WALTER WILSON CROSBY; the second part with the Maryland mineral industries, by WILLIAM BULLOCK CLARK and EDWARD B. MATTHEWS; the third part is on the limestones of Maryland with special reference to their use in the manufacture of lime and cement, by EDWARD B. MATTHEWS and JOHN S. GRASTY. The combination of scientific character and practical value which mark these papers indicates how valuable to a state a Geological Survey may be and still without duplicating the work of the national organization. J. B.

9. *Report of the Conservation Commission of Maryland for 1908–1909*, BERNARD N. BAKER, WM. BULLOCK CLARK, EDWARD HIRSCH, *Commission.* Pp. 204, with 13 plates and 13 figures. Baltimore, Dec. 31, 1909.—This report is the outcome on the part of Maryland of the Conference of Governors called by President Roosevelt at the White House on May 13–15, 1908. It contains chapters on mineral resources, agricultural soil resources, forest resources, reclamation of swamps, water resources, fisheries, oyster supply, game preservation, scenery, public health, good roads, recommendations. A perusal of these chapters calls attention especially to the present wasteful neglect of forests and public health. The value of the commission, if it succeeds in educating the public to the enactment and enforcement of needed state laws, will be almost incalculable. J. B.

10. *A Preliminary Report on the Geology of the Monarch Mining District, Chaffee County, Colorado;* by R. D. CRAWFORD. Pp. 78, with 11 plates and 3 figures. Bulletin I, Colorado State Geological Survey, Boulder, Col., 1910.—This report gives the geology of a region about five miles square situated on the east slope of the Sawatch Range. Ore was first discovered in 1878 and since that time the district has passed through various stages of prosperity, its fortunes at present being on the increase. The report is, therefore, of timely appearance. The district embraces an area of pre-Cambrian granite, partly enclosing an area of Paleozoic limestones underlaid by some quartzite. Across this older and deformed structure have broken massive intrusives of post-Devonian age. The mines are reported on in detail and the ores are classified under five types. J. B.

11. *Geology of the Grayback Mining District, Costilla County, Colorado;* by HORACE B. PATTON, CHARLES E. SMITH, G. MONTAGUE BUTLER, and ARTHUR J. HOSKIN. Pp. 111, with

11 plates, Bulletin II, Colorado State Geological Survey, Boulder, Col., 1910.—This bulletin is the result of six weeks' work in the field by students and teachers under the direction of the Department of Geology of the Colorado School of Mines during the summer of 1909. The tract surveyed embraces about thirty square miles lying due east of Blanca Peak, the highest peak of the Sangre de Cristo Range. Pre-Cambrian gneiss and mica schist on the west are flanked by Carboniferous sandstones and limestones. The latter are intruded by masses of diorite, monzonite porphyry, and felsite; certain large areas being so cut up by dikes that their separate mapping was impossible. An overprint pattern was, therefore, used to designate such areas. J. B.

12. *Erdbeben. Eine Einführung in die Erdbebenkunde;* von William Herbert Hobbs. Erweiterte Ausgabe in deutscher Übersetzung, von Professor Dr. Julius Ruska. Pp. xxxii, 274, with 30 plates and 124 figures. Leipzig, 1910 (Quelle and Meyer).—It is pleasant to record that the work by Professor Hobbs on earthquakes has met with so favorable a reception that a German translation has been made. Studies of the most recent earthquakes, especially that of Messina, are included, and a chapter on the methods of building construction adapted to earthquake regions has been added. The volume considers the evolution of the science of seismology, the origin of earthquakes, the broad relations of earthquake regions on the earth, the detailed phenomena of earthquakes, local and distant effects, and methods of earthquake study, in the field and office. In the introduction Professor Hobbs calls attention to the rapid growth of the subject and its divergence into two distinct fields, that of the geophysicist, to be pursued by mathematical and physical methods, and that of the geologist, requiring field studies. J. B.

13. *Les Variations Périodiques des Glaciers* rédigé par Dr. Ed. Brückner et E. Muret. Fourteenth report, 1908. Commission Internationale des Glaciers. Extrait des *Annales de Glaciologie*, iv., pp. 161–176, 1910. Berlin, 1910 (Frères Borntraeger).—As noted in the introductory paragraph, it is evident that during 1908 the retreat of glaciers was a general phenomenon. The marked growth of a group of Norway glaciers had diminished slightly in 1908. These and certain Swiss glaciers offer the only noteworthy exceptions in the table. The commission by this report continues to lay the basis for a future exact study of glacial variations and from them of climatic variations in various parts of the world. Such an accumulation of data for the use of the next and future generations is one of the most far-sighted movements of present science. J. B.

14. *Études Glaciologiques, Tirol Autrichien, Massif des Grandes Rousses.* Service d'études des Grandes Forces Hydrauliques (Région des Alpes) Ministère de l'Agriculture 1909. I—*Forages Glaciaires à Grande Profondeur* par MM. Flusin et Bernard. II—*Études Glaciares, Géographiques et Botaniques dans le Massif des Grandes Rousses* par MM. G. Flusin, C.

JACOB et J. OFFNER. Pp. vi, 112, plates iv+ix, maps iii.—In the preface attention is called to the great importance of complete investigation of the water resources of every region in order that the factors may be understood which control the run-off throughout the year. In the Alps not only do the lakes act as storage reservoirs but the glaciers also. The latter discharge their stores especially during the summer and also more abundantly during warm cycles of years, at the present time the glaciers being in general retreat. They thus act as storage reservoirs in ways different from lakes though equally important. Investigations upon glaciers have, however, been hindered by the lack of knowledge regarding their depth, the third dimension which is so readily ascertained for measuring the cross-section and run-off of rivers and lakes. The first part of the present work gives the details of the methods devised and successfully used for boring to the bottom of glaciers and thus determining their cross-section. The second part gives detailed studies and maps of the massif of the Grandes Rousses and its glaciers, the region where these methods were pursued. There is thus given here a very complete investigation of a group of glaciers considered as reservoirs of water stored in the solid form, a unique hydrologic investigation whose methods will doubtless be extended to other regions. J. B.

15. *Beiträge zur Geologie der Samoainseln;* von I. FRIEDLÄNDER. Abh. k. Bäyer. Akad. Wiss., II Kl., xxiv, Abt. III, pp. 509–541. Based on visits to all the main islands of the Samoa group, the writer gives a general sketch of their geological character and considerable detail regarding the most striking features of each. Since the islands are purely volcanic, it mostly concerns the arrangement and relative age of the new and old craters, lava masses and tuffs. The writer has visited also Hawaii and Fiji and, agreeing with Woolnough that the latter consists of volcanics piled on the remnants of a continental platform, he suggests that the volcanic masses forming the other two, if we consider them to rise wholly from the ocean floor, are of enormous dimensions, entirely beyond anything known on the land. In Hawaii, taking into account the small volcanic islands and coral reefs, the ridge stretches some 1500 miles with a maximum height of 30,000 feet. In Samoa the ridge is 300 miles long and 20,000 feet high. This suggests that these, like Fiji, are built on a submerged continental platform. Two maps and a number of excellent plates of photographs accompany the article.

L. V. P.

16. *Artificial Lava Flow and its Spherulitic Crystallization.*—Under this title in the August number of this Journal of the current year (p. 97), the writer described an accidental flow of glass, and the spherulites which formed in it. In the article it was stated that the conditions obtaining, and the relative positions of the specimens described, were unknown. Since then the writer has received a letter from Mr. R. L. Frink of Columbus, Ohio, a

technical engineer who has made a special study of the glass industry. Mr. Frink believes that it was an error to attribute the specimen figured in A of the plate to simple flowage. He sends a specimen which closely resembles it and says that these can be produced at will in the flattening ovens by laying sheets of glass one upon the other and submitting them to the action of heat for varying periods of time, and the longer the time the more opaque the mass will become. The latter statement refers to the greater number of minute spherulites. The specimen shows that the glass plates have been softened to a viscous condition, from the bent and wavy layers they present, and are completely welded. The plane of each two contiguous surfaces is marked by a white film composed of innumerable minute, white spherulites separated by clear green glass. In explanation of this it has been suggested to the writer that the film of air between the plates may have helped in the process. This seems quite possible, for as the glass softened, the gas may have rendered this layer less viscous, by entering into the molten solution, to the degree where crystallization could take place, while the intermediate layers were too viscous to permit of this. With respect to the specimen of Kane glass figured, it may be then, as Mr. Frink suggests, that it was not formed by actual flowage. A possible explanation for it may be that it represents successive droppings of portions of melted glass from the broken furnace upon one another, which flattened down, and along whose flattened surfaces the films of spherulites developed. It appears too thick and irregular to have been made purposely, as suggested by Mr. Frink.

In regard to the formation of spherulites in glass Mr. Frink says that he thinks that the difference in specific gravity between them and the glass is too slight to condition their arrangement, and that this is chiefly due to the viscosity, temperature, and flow of the glass. Sometimes they are at, or near, the surface; sometimes 12 or 18 inches below it there will be a stratum containing innumerable numbers of them. In general, the deeper ones are of larger dimensions. He regards them as being formed at the line of "mean flow," which may perhaps indicate one where the conditions are right for crystallization, being neither too hot on the one hand, nor too stiff and viscous on the other.

L. V. PIRSSON.

17. *Economic Geology;* by HEINRICH RIES. 3d edition. Pp. 589, 237 figs., 56 pls. New York (The Macmillan Company).—This work, originally published in 1905, has already gone through two editions and firmly established itself as a text-book of its subject. The book, in the present edition, has been revised and considerably amplified in scope and size. While its general arrangement remains the same, much more space has been devoted to the detailed description of the individual mineral districts. The number of the text illustrations has been increased nearly three times, while the number of the plates has been more than doubled.

W. E. F.

18. *The Ore Deposits of New Mexico;* by WALDEMAR LINDGREN, LOUIS C. GRATON and CHARLES H. GORDON. U. S. Geol. Sur., Professional Paper No. 68, 1910. Pp. 349, 33 figs., 22 pls.—The mining districts of New Mexico form a belt extending from the north central part of the state to the southwest corner. Silver or gold, or both, are present in nearly all of the districts and as a rule are accompanied by copper, lead and zinc. A great number of types of ore deposits are represented in New Mexico. Among them are copper and iron ores in sedimentary beds; fissure veins; mineralized shear zones; lenticular bodies; replacement deposits; contact metamorphic deposits; placers.

The pre-Cambrian schists contain disseminated ore in shear zones and veins of copper and zinc sulphides with some gold but little silver; the Paleozoic limestones carry irregular copper, lead and zinc deposits; the intrusive porphyries and granites contain fissure veins with gold and silver; finally, the rhyolite and andesite inclose fissure veins rich in gold and silver. The major part of the deposits occur in or near the many, usually small, areas of intrusive rocks—mostly monzonites—which extend across the state.

The study of the ore deposits of the state has resulted in the establishment of various periods for their formation with distinct characteristics for each period. Thus the pre-Cambrian deposits are mainly lenticular veins, shear zones and "fahlbands" in schists which carry chiefly gold and copper. In late Cretaceous or early Tertiary time widespread intrusion took place along what is now the mining belt. After these intrusions most of the metal deposits were formed; they consist of contact-metamorphic deposits, veins, shear zones and silver-lead replacements in limestone. In the latter part of the Tertiary period lava flows occurred in certain sections and at several places fissure systems in these rocks were filled with gold and silver ores. The age of the copper deposits in sandstone has not been fully established. Their formation probably commenced after the general uplift in the early Tertiary, when atmospheric waters began to penetrate the Red Beds, from which the deposits are believed to have concentrated their copper ores. W. E. F.

19. *Meteor Crater in Northern Central Arizona;* by D. M. BARRINGER. Pp. 24, with 21 plates and maps (privately printed).—The Meteor Crater in Arizona, or Coon Butte as it was earlier called, is unquestionably one of the most remarkable spots on the earth and the problems that it presents have never been faced elsewhere. It has been described by numerous writers since attention was first called to it by A. E. Foote in 1891.* A very full and satisfactory account† of the locality and the associated meteoric material with a discussion of the origin of the crater was given by G. P. Merrill two years since in volume 1 of the Quarterly Issue of the Smithsonian Miscellaneous Contributions for January,

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* See this Journal (3), xlii, 413, 1891.

† Ibid (4), xxv, 265, 1908.

1908 (pp. 461–498, plates lxi–lxxv). The present paper, the title of which is given above, was read by Mr. Barringer at the Princeton meeting of the National Academy of Sciences a year ago; it embraces the results of his own extensive explorations, and the conclusions drawn from them. The thoroughness with which the study of the locality has been carried on will be understood from the fact that no less than twenty-eight holes have been drilled in the central portion of the crater, some of them being carried to a depth of 1000 feet and more, below the level of the original plain.

The chief features of Meteor Crater, briefly characterized, are as follows: A crater-like depression a little more than three-quarters of a mile in diameter, with an average depth from the rim to the more or less level floor of about 570 feet. The walls, in part nearly perpendicular, are composed of limestone and underlying sandstone strata, which are tilted up and dip away from the center at varying angles. These strata, it is estimated, have been vertically lifted more than 100 feet from their original position, involving an uplift of perhaps some 20 to 30 million tons of rock. Further than this, many million tons of rock have been ejected from the crater. This includes great masses of solid limestone, from fifty to several hundred pounds in weight; the larger fragments lie near the crater's rim, the smaller ones extend to a distance of from one to one and one-half miles. The ejected rock material also includes the sandstone much of it in the form of "silica" or rock flour; this last makes up perhaps some 15 or 20 per cent of the entire material thrown out of the crater. Within the crater there are also enormous quantities of the sandstone which has been reduced to a fine pulverulent condition, while other portions are metamorphosed, a part showing a strongly marked slaty structure, and part, having undergone a kind of aqueo-igneous fusion, having a light, spongy consistency, with more or less opalescent quartz.

All of these phenomena, of the extent and magnitude of which it is difficult to form a conception, have been apparently accomplished without volcanic agency,* and are to be referred, as recent investigators agree, to the impact of an enormous meteoric mass of almost incredible size, such as we have no parallel for elsewhere on the earth. The writer concludes that "the crater was made, not by a single giant meteorite, but rather by a compact cluster or swarm of many thousand of shale ball meteorites and also possibly other iron meteorites traveling together as the head or part of the head of a small comet."

Many thousands of specimens of meteoric iron have been found in the neighborhood of the crater, up to over 1000 pounds in weight; some of the smaller ones have been found at a distance of five and one-half miles from the crater. It was the discovery of these iron masses in 1891 that first attracted attention to this locality; they have been usually named from the neighboring Canyon Diablo. As is well known this meteoric iron has some important characters which need not be recalled here.

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* Since the above statements were put into type, a paper on this locality by J. M. Davison has been published in Science (Nov. 18, p. 724). He returns to the idea of volcanic action, early suggested, and, speaking of the pulverulent sandstone, he remarks: "It rather suggests long-continued deposition of this powder, with occasional pieces of rock, by geyser action and a final explosion or series of explosions that closed the drama."

In addition to the iron, a unique feature of the locality are the "shale balls," of which great quantities have been discovered; the largest of these weighs something over forty pounds. These are generally rounded or globular disintegrating masses of meteoric iron and nickel oxide, many of them containing solid nickel-iron centers. They have more or less of a shaly structure. The iron of these balls contains chlorine in small amount, which is practically absent in the Canyon Diablo siderites and to this their disintegration is attributed. The shale balls, except when imbedded in the silica, oxidize to a hard compact iron shale, though often leaving an iron nucleus. The meteoric material exists not only on and near the surface but has also been brought up by the drills, often in the form of small specks of nickel-iron oxide, even from a depth of 680 feet below the floor of the crater, that is about 1200 feet below the original plain level.

It is, doubtless, disappointing that thus far the drills have failed to find the main mass of the projectile which did such a a tremendous work; nor has it been located by experiments with the dipping needle. We must, however, accept the decision of the author, who says: "We are thus compelled to conclude that the mass which made the crater, and which, as has been suggested above, may have been the metallic head of a small comet, lies in the bottom of it somewhere; for if it was a compact cluster of iron meteorites which made the crater—there is certainly a great deal of evidence in favor of this theory and none against it—it would seem from the evidence most unlikely that any considerable portion was expelled after the cluster had penetrated some 1100 to 1200 feet of limestone and sandstone strata. When the metallic mass is found, it would seem probable that it will be found to have partially oxidized, much after the manner of the buried shale balls, in which event it would still possess great commercial value. As yet we do not know where it is in the large area covered by the crater, but I personally think it probable that, in the form of a vast number of shale balls and perhaps Canyon Diablo siderites lying more or less closely together, most of it will be found far over in the southern or southeastern portion of the crater, where no prospecting by the drill has been done, and that some of it, if not the larger part of it, will be found underneath the perpendicular cliffs which form the southern wall."

Mr. Barringer's memoir, of which only a brief account has been given, closes with a bibliography of the subject, and is accompanied by a large number of fine plates, giving views of the crater from different points, the masses of limestone rock thrown out from it, and also many illustrations of the altered sandstone, the shale balls and iron in their various forms.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The National Academy of Sciences.*—The autumn meeting of the National Academy was held at St. Louis on Nov. 8 to 10. The following is a list of papers read:

GEORGE C. COMSTOCK: Some problems of stellar motion.

EDWIN B. FROST: Preliminary note on the Sun's velocity with respect to stars of spectral type A.

FOREST R. MOULTON: On the origin of binary stars.

JOHN M. COULTER: The Cycadophytes.

WILLIAM TRELEASE: A monograph of Agave in the West Indies.

REGINALD R. GATES: The mode of chromosome reduction.

WILLIAM M. DAVIS: The Front Range of the Rocky Mountains in Colorado.

GEORGE T. MOORE: Mutualism, parasitism and symbiosis.

JOHN U. NEF: Sugar chemistry from the new chemico-physical standpoint,—or the behavior of the sugars toward enzymes, alkalies and oxydizing agents.

WILLIAM A. NOYES and LUTHER KNIGHT: Molecular rearrangements in the camphor series: isocamphoric acid.

IRA REMSEN: A molecular rearrangement leading to the formation of anidines.

On Tuesday evening a lecture was delivered by Prof. T. C. Chamberlin on China.

2. *Maryland Weather Service*, WM. BULLOCK CLARK, Director, Vol. III; *The Plant Life of Maryland;* by FORREST SHREVE, M. A. CHRYSLER, FREDERICK H. BLODGETT and F. W. BESLEY. Pp. 533, with 39 plates and 15 figures. Baltimore, 1910 (Johns Hopkins Press).—Of the two volumes previously issued in the Maryland Weather Series, the first discussed the physiography and the meteorology of the State, and the second contained a study of the climate and weather of Baltimore and its vicinity. The present volume has a somewhat wider range, dealing with the plant life of the State, particularly as regards its distribution, not only as affected by climate and the physiography of the three prominent zones, but also determined by the nature of the soil. In 1904 a botanical survey of the State was undertaken by Dr. Forrest Shreve, and the important results of the work done by him and his associates are now presented to the public. The close association of the Geological Survey with the Weather Service, both being under the directorship of Professor Clark, has been a fortunate arrangement for the state, both as regards economy of management and the thorough coöperation of the investigations.

3. *International Institute of Vulcanology at Naples.*—At the recent Geological Congress held in Stockholm, a proposal was made by Dr. IMMANUEL FRIEDLÆNDER for the establishment of an International Institute of Vulcanology at Naples. This plan was accepted by the Congress and a circular has recently been issued giving details and calling for contributions to this important cause. The Institute, when established and fully equipped,

will, for the first time, provide for continuous and systematic observations of all volcanic phenomena, both physical and chemical. How important results may be looked for from this enterprise may be fairly estimated from the value of what has already been done by the small and meagerly supported observatory on Vesuvius. It is proposed to raise before January, 1912, a building fund of 1,500,000 lire, while promises of annual contributions aggregating 50,000 lire are also needed. Dr. Friedlænder leads the list of contributions with the sum of 100,000 l. for the fund and 10,000 l. as an annual contribution for ten years; it is to be hoped that his appeal may have generous support. His address is Villa Hertha, Vomero, Naples.

4. *Studies in Spiritism;* by AMY E. TANNER. With an introduction by G. STANLEY HALL. Pp. xxxix, 408. New York, 1910 (D. Appleton & Co.).—This is a thoroughly sane and fair-minded presentation of a subject in which great interest is felt, and about which there is a wide divergence of opinion. The statements of the author and her observations based upon repeated sittings with Mrs. Piper will appeal all the more strongly, at least to those who tend to be sceptical in regard to matters connected with telepathy and spiritism, in that she entered upon her work not "with any spirit of antagonism, but rather in a spirit of doubt that inclined towards belief." The conclusion to which her investigations have led her are expressed as follows; "I was inclined to think that I should finish the work a believer at least in telepathy. So far is this from being the case that the more I have read and seen of such experiences, the more amazing has it come to seem that two theories like telepathy and spirit communication, which are unsupported by any valid evidence, should have obtained credence to-day; and the more incomprehensible has it come to be that men should be willing to stake their professional reputations upon the inaccuracies and rubbish that pass for 'scientific' facts in these matters . . ." The volume was undertaken at the suggestion of Dr. G. Stanley Hall and has been prepared under his supervision; the introduction is from his hand.

Psychism; by Mr. HUME. Pp. 157. London and Felling-on-Tyne (The Walter Scott Publishing Co.).

OBITUARY.

WILLIAM HENRY BREWER, Professor emeritus of Agriculture in the Sheffield Scientific School of Yale University, died at New Haven on November 2 at the age of eighty-two years. A notice will be given in a later number.

DAVID P. PENHALLOW, Professor of Botany in McGill University, Montreal, died on October 26 at the age of fifty-six years.

DR. OTTO LUEDECKE, Professor of Mineralogy at the University of Halle, died in October at the age of sixty-six years.

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FOURTH SERIES

VOL. XXX—[WHOLE NUMBER, CLXXX.]

INDEX TO VOLUMES XXI–XXX.

NEW HAVEN, CONNECTICUT.

JANUARY, 1911.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Index Number one dollar per copy. Sent only to those ordering it.

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OF

VOLUMES XXI–XXX OF THE FOURTH SERIES.

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